THE INFLUENCE OF SURFACE MATERIALS ON RAW COTTON PROCESSING FRICTION

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

Abstract

Textile processing friction may be affected by surface materials on cotton. These materials include, in addition to man-induced contaminants, naturally occurring substances such as waxes, metals, sugars, and "other" residues. Concentrations of these materials may vary depending on fiber history and other factors. We, however, are able to quantify through various standard analytical tests, concentrations of these materials. Since little information is presently available in the area of just what contributions these surface materials make to overall processing friction and quality, a brief study was designed to do so. Work using standard analytical procedures to measure levels of surface materials are conducted on cottons from different growing areas. Fiber frictions in the form of RotorRing measurements are also determined for each sample. Subsequent relationships between metal, wax, and "other" residues and how they may affect textile fiber processing friction are explored.

Introduction

Harvested cottons have materials on their surfaces that can affect processing and fiber quality. In addition to any man-induced contaminants such as oils, insecticides, herbicides, and defoliants, all cotton surfaces have been found to contain varying levels of naturally occurring substances such as metals, waxes, and other residues (including carbohydrates, phosphates, silicates, chlorides, and carbonates). Concentrations may vary depending upon fiber histories, variety, fiber maturity and length, micronaire, area of growth, open boll exposure conditions, and harvesting conditions.

Waxes and sugars are nearly all located on the primary wall of the cotton fiber (Perkins, 1981). Wax, which is highly related to the fiber micronaire (Perkins, 1971, Brushwood, 1998), may vary in levels from 0.3 to 1.3% of the dry fiber weight. Except for small percentages of the annual crop that are contaminated with insect honeydew, naturally occurring plant sugars are present. Concentrations of these sugars have been found to range from 0.1 to over 2.0% in some cases (Brushwood and Perkins, 1993). As these sugars increase on fiber surfaces, the potential for the fiber to be sticky in processing also increases.

Metals on cottons are traditionally determined by ashing (Rollins, 1956, Brushwood and Perkins, 1992, 1994) the cotton and dissolution of the ash before determining appropriate metals. The four most predominant metals, potassium, calcium, magnesium, and sodium, can have total concentrations as low as 0.2 to over 0.8% based on the dry weight of the fiber. High levels of the metals calcium and magnesium on cottons can cause formations of insoluble salts in textile dyeing and finishing processes that inhibit levelness. Thus, fiber quality is affected. Other metals may contribute to yellowness in finished goods (Brushwood and Perkins, 1994). Therefore, it is important to measure and quantify metals in cottons.

How surface materials on cottons affect processing friction is an important consideration to textile manufacturers. This is especially true with the modern trends toward increasing production throughput speeds. The purpose of this work was to quantify metals, waxes, and other materials on the surfaces of selected cottons from different growing areas, and determine the processing frictional potential of these fibers before and after removal of these materials. This was to be achieved by, 1. -Determining RotorRing friction values of the raw cottons, 2. – Extraction of the waxes and measuring RotorRing friction, and 3. – Extraction of total surface materials and again measuring RotorRing friction. Correlations between rotor ring friction values measured at these three stages and variations in metal, wax, and "other materials" are made in attempts to predict their affects on fiber friction.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1291-1294 (2001)
National Cotton Council, Memphis TN

Experimental

Raw cottons, both foreign and domestic, in our inventories from a variety of different growing areas and available to us from various industry sources were gathered and conditioned in a laboratory atmosphere (24°C and 55 to 65% relative humidity) for at least 30 days before moisture contents were determined. Moisture contents (triplicate measurements per cotton) averaged 7.0 ± 0.26%. All subsequent metal, wax, and total surface extractable concentrations were calculated on a dry fiber basis using the 7.0% moisture factor to adjust for dry weight.

Metals

Metal concentrations on all were determined by ashing the cotton and analysis by atomic absorption according to the procedure outlined in previous work (Brushwood and Perkins, 1994). Each sample was prepared in triplicate. Hence, metal concentrations presented represent average values for three determinations per cotton.

Twenty cottons – 3 each from the U. S., Central Africa, China, Greece, Russia, and the Sudan plus single samples from Pakistan and Syria were submitted to the Institute of Textile Technology (ITT) laboratory in Charlottesvile, VA., for RotorRing friction testing. A description of the testing procedure is outlined in the literature (Ghosh, et. al., 1992). At least 4 replicates for each fiber-to-metal (f/m) and fiber-to-fiber (f/f) friction were conducted on each sample. Data presented here represents average values for these friction tests.

Waxes and Other Surface Materials

Fourteen non-insect honeydew contaminated domestic cottons, (2 each from Arkansas, California, Tennessee, Texas, and Georgia and 4 from Mississippi) were selected for this study. Fiber micronaires for these samples ranged from 3.8 micronaire for Texas to 5.1 for the California samples. Strength measurements ranged from 25.2 to 31.7 g/tex. and Upper Half Means varied from 1.05 to 1.17 inches. Each was subjected to 6-hour soxhlet extractions with trichloroethane to remove surfaces waxes. Likewise, separate samples were subjected to 6-hour soxhlet extractables with 95% ethyl alcohol to remove total surface materials (waxes, organic acids, sugars, hydrocarbon contaminants, and other residues). Potassium ferricyanide (Perkins) reducing sugar tests were run in triplicate on the unextracted, trichloroethane extracted, and alcohol extracted samples to determine residual sugar content at each stage. The above analytical procedures and methods are described in a previous report (Perkins, 1971).

Wax and alcohol extraction values were determined from averaging 18 different extractions (3 gram per extraction) for each sample. . Thirty grams or more of each sample (a total of 42) were also submitted to ITT for RotorRing friction testing. Average wax and "other" surface contaminant results were used in conjunction with reported fiber friction values for these samples at each extraction stage to study relationships.

Results and Discussion

Effect of Metals on Friction

Averages for metals determined by atomic absorption spectroscopy for the domestic and 7 different foreign cottons are shown in Table 1. The most abundant metal, potassium varied from just below 4500 parts per million (ppm) for U. S. and Greek cottons to about 6000 ppm for Central African and Pakistani samples. Calcium concentrations ranged from 700 ppm for Chinese to 1445 for the Pakistani cotton. Magnesium levels ranged from 485 ppm for China to 695 ppm for Central Africa. Higher light metal levels were generally determined to originate from areas that open bolls are traditionally exposed to little or no moisture (overhead irrigation or morning dew, etc.) Typical examples are reflected in metal results from Central Africa, Pakistan, and Russia.

Frictional values (in joules) for fiber-to-metal (f/m) and fiber-to-fiber (f/f) RotorRing friction tests on the representative foreign and domestic samples that also had metals determined on them are listed in Table 2. General comparisons of f/f and f/m friction show f/f friction values are 1.5 to 2.2 times higher than f/m values for the same fiber. Fiber-to-metal (f/m) friction measurements ranged from a low of 6369 joules for Pakistani to a high of 9457 joules for U. S. grown cottons. Fiber-to-fiber (f/f) friction measurements ranged from a low of 13651 joules for Syria to 19047 joules for Chinese cottons.

Correlations between average RotorRing friction measurements and individual and total light metal contents for this series of samples are transposed. As the metal concentrations increase f/m and f/f friction tends to decrease. For example, the coefficient of simple correlation between potassium level and f/m and f/f friction measurements is – 0.63 and – 0.61, respectively (Figure 1.). Similarly, the same relationships are seen with calcium level (Figure 2.). The coefficient of simple correlation is – 0.92 and –0.83, for f/m and f/f friction, respectively. Magnesium correlations with the same friction measurements were somewhat lower at – 0.39 and – 0.44 for f/m and f/f friction, respectively. When the total potassium, calcium, and magnesium content was correlated with friction, the coefficient of simple correlation for f/m and f/f friction is –0.80 and – 0.71, respectively (Figure 3.). Hence, higher concentrations of the 3 most abundant metals on raw cottons actually tend to promote reductions in processing friction.

Effect of Surface Waxes on Friction

Extractable wax concentrations on the domestic cottons ranged from an average of 0.37% on the Tennessee to 0.53% on the Arkansas cottons (Table 3.). Sugar levels, which averaged from 0.14% in Georgia to 0.39% in Arkansas, were not removed from the cotton by the trichloroethane wax extractions. They were, however, removed with the alcohol extraction. The coefficient of simple correlation between initial f/m and f/f friction measurements (Table 4.) and fiber wax content is – 0.79 and – 0.41, respectively (figure 4.). Hence, as surface wax content increases, fiber friction is seen to decrease. The correlation between wax content and measured fiber micronaire is – 0.78 (figure 5.). As the micronaire increased, wax content decreased. Based on total alcohol extractables, wax concentration on these domestic cottons ranged from 23% of total extractable surface materials for California to about 48% for Georgia cottons.

Effect of Total Surface Residues on Fiber Friction

Average total surface extractions (including waxes, sugars, and other residual materials) from different U. S. growing areas ranged from a high of 1.65% for California and lows of about 1.0% for Georgia and Arkansas cottons. The California samples contained an average lower percentage of wax (Table 3.) The Georgia and Arkansas samples had the higher percentage overall of wax content. Coefficients of simple correlation between total extracts and f/m and f/f friction for this series of cottons are 0.86 and 0.75, respectively (figure 6.).

Average non-wax residues (total – wax extracts) ranged from 0.52% for Georgia (lowest overall friction) to about 1.0% for the three growing areas with the higher friction measurements, Mississippi, Tennessee, and California. These non-wax residues (including sugars), when correlated with f/m and f/f friction, resulted in coefficients of simple correlations almost exactly the same as the above relationships at 0.87 and 0.74, respectively (figure 7.). The two previous examples (figures 6. and 7.) show that, as non-wax related surface residues increase, the potential for higher processing friction increases.

Conclusions

A brief study of selected domestic and foreign raw cottons was conducted to measure metal, wax, and other residual materials on their surfaces. RotorRing friction measurements determined for all cottons were subsequently correlated with quantitatively determined concentrations of these surface materials. Correlations between levels of the three most abundant metals on surfaces (potassium, calcium, and magnesium) and RotorRing fiber friction indicated a general decreasing of friction as metal content increased.

Fiber wax contents for 14 domestic cottons varied from 0.37 to 0.53%. Correlations of wax levels and RotorRing friction showed a high relationship between reductions in fiber friction as wax content increased. Also, as fiber micronaire decreased, surface waxes increased. Normal uncontaminated raw cottons obviously get their lubricity from natural waxes with some contributions from elevated concentrations of light metals such as potassium, calcium, and magnesium.

Average total surface extractions for the domestically grown cottons ranged from 1.0 to 1.65%. Corrections for wax content reduced these values to 0.52% for Georgia to 1.26% for California cottons. Highly positive relationships between non-wax extractables and RotorRing friction measurements were found. Results clearly indicate that as non-wax surface residues increase, or the ratio of wax/total surface extractables decreases, the potential for processing friction increases. Future studies with the domestic cottons will determine metal content at all three stages (unextracted, wax removed, and alcohol removed) of residual material.

References

Brushwood, D. E. 1988. Effects of Heating on Chemical and Physical Properties and Processing Quality of Cotton. Textile Research Journal, Vol. 58, pp 309-317.

Brushwood, D. E. and Perkins, H. H., Jr. 1992. Metal Content of Cotton as Related to Variety, Area of Growth, and Other Factors. Proceedings of Beltwide Cotton Conferences, National Cotton Council, Memphis, Tn, pp 1454-1456.

Brushwood, D. E. and Perkins, H. H., Jr. 1993. Cotton Sugar and Stickiness Test Methods. Canadian Textile Journal, September issue, pp 54-62.

Brushwood, D. E. and Perkins, H.H., Jr. 1994. Determining the Metal Content of Cotton. Textile Chemist and Colorist, Vol. 26, No. 3, pp 32-35.

Ghosh, S., Rodgers, J. E., and Ortega, A. E. 1992. RotorRing Measurement of Fiber Cohesion and Bulk Properties of Staple Fibers. Textile Research Journal, Vol. 62(10) pp 608-613.

Perkins, H. H., Jr. 1971. Some Observations About Sticky Cottons. Textile Industriess 135 (3), pp 49-64.

Perkins, H. H., Jr. 1981. Effects of Washing on Fiber Properties, Dust Generation, and Processing Quality. Textile Res. J., Vol. 51, pp 123-127.

Rollins, M. L. 1956. The Cotton Plant. American Cotton Handbook, Vol. 1, Chapter 3. John Wiley and Sons Publishers, NY.

Table 1. Metals in U. S. and foreign-grown cottons.

	Average metal content (ppm)				
LOCATION	K	Ca	Mg	Na	Fe
C. AFRICA	5940	1040	695	254	60
CHINA	4600	700	485	161	24
GREECE	4330	950	590	145	67
PAKISTAN	5970	1445	685	400	52
RUSSIA	6030	1010	645	216	38
SUDAN	5080	775	655	167	114
SYRIA	5380	1265	575	161	40
U. S. A.	4340	830	575	168	46

Table 2. RotorRing frictional ratings of raw cottons from U. S. and foreign growing areas.

LOCATION	*fiber/metal	*fiber/fiber
CENTRAL AFRICA	8493	15981
CHINA	9215	19047
GREECE	9008	16375
PAKISTAN	6369	14681
RUSSIA	8797	14303
SUDAN	8652	17935
SYRIA	7465	13651
U. S. A.	9457	16509

*units in joules.

Table 3. Average surface residues for six domestic growing areas.

LOCATION	M*	WAX (%)**	TOTAL EXTRACT (%)***	R. S. (%)****
ARKANSAS	4.2	0.53	1.05	0.39
CALIFORNIA	5.1	0.39	1.65	0.38
GEORGIA	4.2	0.48	1.00	0.14
MISSISSIPPI	4.4	0.43	1.45	0.25
TENNESSEE	4.7	0.37	1.50	0.33
TEXAS	3.8	0.48	1.30	0.28

M* = fiber micronaire
WAX** = trichloroethane extractables
TOTAL*** = alcohol extractables
R.S.**** = Perkins test reducing sugars

Table 4. RotorRing friction values for domestic cottons.

	*f/m Friction			*f/f Friction		
LOCAT.	INIT.	WAX EXTR.	TOT. EXTR	INIT.	WAX EXTR.	TOT. EXTR.
AR.K.	8090	12090	12270	16520	21700	25100
CALIF.	10160	13930	16170	18830	25340	26870
GA.	8640	10520	12530	15850	17890	25260
MISS.	9010	10300	13150	17020	20150	25260
TENN.	9060	11300	11300	16900	21360	22800
TEXAS	8840	12190	12580	18110	21850	23060

* units in joules.

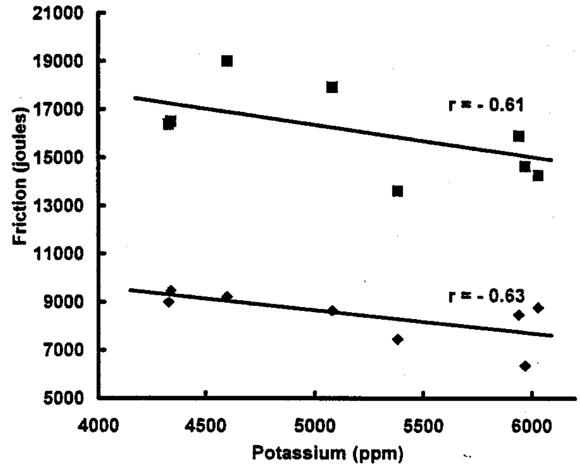

Figure 1. The relationship of fiber potassium content and measured rotor ring friction.

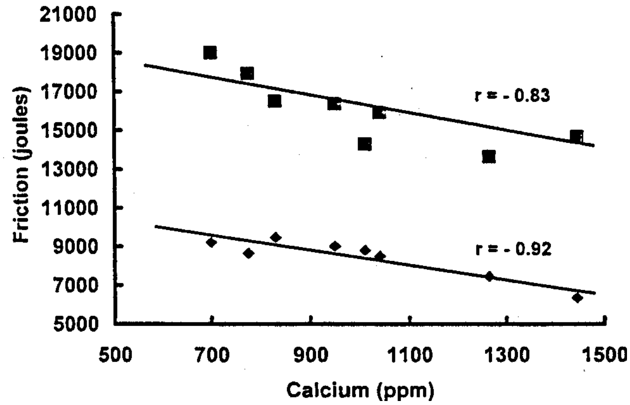

Figure 2. The relationship of fiber calcium content and measured rotor ring friction.

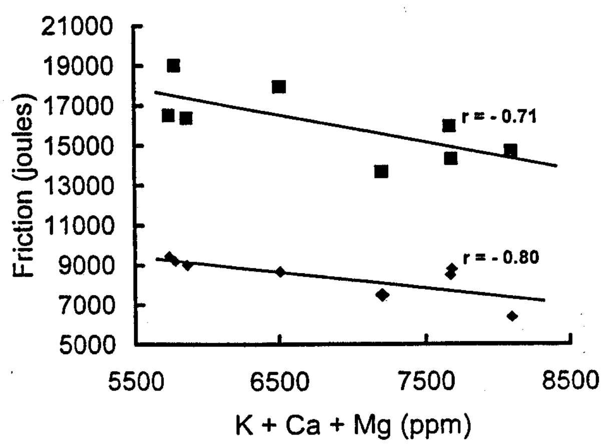

Figure 3. The relationship of total light metal content and measured rotor ring function.

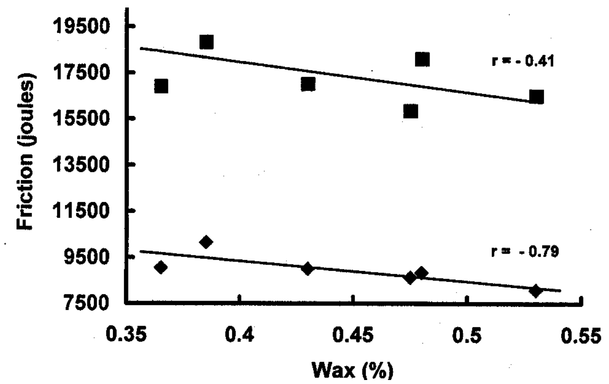

Figure 4. The relationship of surface wax content on rotor ring friction - 6 domestic growing areas.

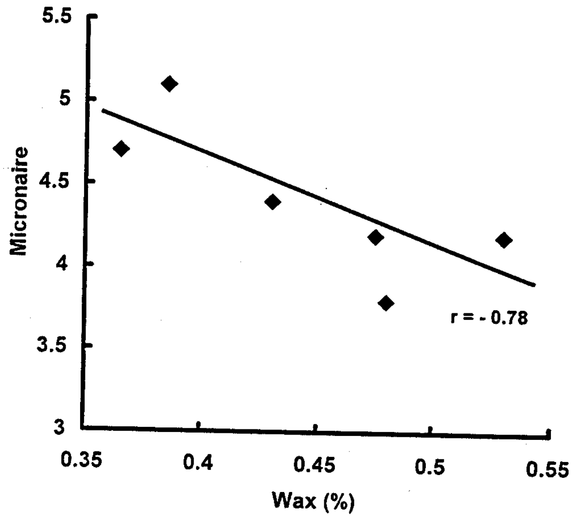

Figure 5. The relationship of fiber micronaire and wax content 6 domestic growing areas.

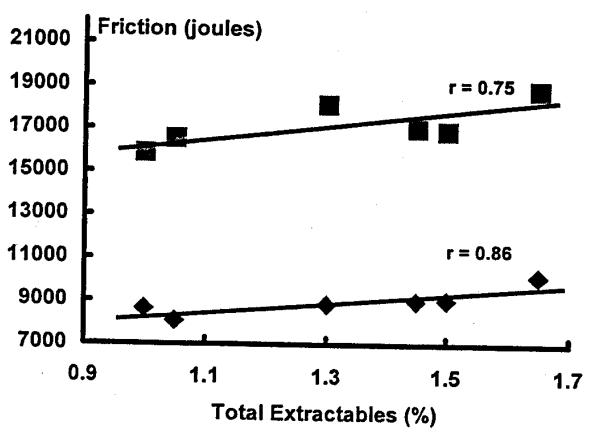

Figure 6. The relationship of total surface extractables to initial friction.

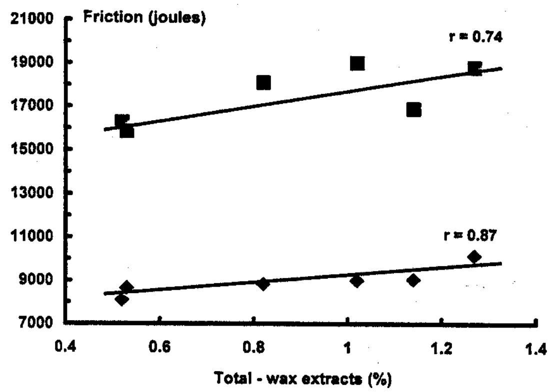

Figure 7. The relationship of "other surface materials" to rotor ring function.