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THE IMPACT OF COTTON FIBER WAX, METALS AND OTHER NATURALLY OCCURING NONCELLULOSIC MATERIALS ON YARN PROCESSING PROPERTIES

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Abstract

Surface extractable noncellulosic materials and metal contents on a series of single season domestically grown cottons that had been previously processed by ring and rotor yarn production systems were determined. Resultant concentrations were correlated with standard fiber HVI physical properties, and produced yarn properties and spin performance. Very positive relationships were found between increasing total surface extractables and fiber/yarn strength, and decreases in short fiber content/evenness thick and thin places. Concentrations of the metals potassium and magnesium were found to be highly related to fiber and yarn color. Increasing levels of calcium tended to promote increases in measured short fiber contents and inconsistencies in produced yarns.

Introduction

Raw cottons contain a number of noncellulosic materials such as wax, sugars and metals whose concentrations are essentially unchanged in the production of textile yarns. Since these materials are generally regarded as surface related, they are suspected of having influences on fiber physical properties, behavior in textile spinning, and yarn properties. Most non-fiberous materials such as seedcoat fragments, trash, and foreign matter picked up by the cotton in the field found in bales are usually adequately removed in the opening, cleaning, and carding processes, therefore; do not create yarn manufacturing problems. Studies by other researchers have documented the effects of seedcoat fragments, trash, and other non-fiberous materials (Perkins and Bragg, 1977) on yarn quality. Reasearch concerning the effects of sugar contamination (both natural and insect) on fiber and yarn quality have been reported (Perkins, 1971, Carter, 1990). There is, however; very little information available on the effects of wax, residual metals, and other solvent extractable noncellulosic materials on fiber and yarn properties.

Naturally occurring waxes generally serve as a fiber lubricant and anti-static agent in textile processing. Concentrations may vary from 0.2 to 1.0 percent depending upon a number of factors including fiber micronaire, length of growing season, fiber maturity, and field weathering, (Perkins, 1971). Potassium, the most abundant metal on cottons, and other metals are important nutrients for the natural development of the fiber. Combined potassium, calcium, magnesium, and sodium (all light metals) normally account for 90 to 95% of the metals on cotton. Other metals such as aluminum, iron, and trace amounts of copper, manganese, and zinc are often present (Heinzleman and O'Connor, 1950, Brushwood and Perkins, 1992, 1994).

The amount of materials removed from the fiber by extraction with ethyl alcohol is considered a very good indicator of noncellulosic content. Residues contain surface wax, sugar, other organic hydrocarbons, and portions of easily removed light metals such as potassium and sodium. Most of the calcium, magnesium, and heavy metals of the fiber are not removed by the ethyl alcohol extraction process.

Cotton fiber friction (cohesion) is defined as the energy required to separate a fiber or fibers from each other or an assembly. This depends on fiber "consistency". Consistency is defined by a number of properties including staple length, surface roughness, and fiber entanglement. Therefore, fiber frictional properties can be highly related to yarn processing performance and quality.

This research project was undertaken to, (1) measure levels of noncellulosic materials and frictional properties on a series of U. S. grown raw cottons representing several different varieties and growing areas and, (2) determine possible relationships between individual noncellulosic material concentrations and frictional properties, and conventional fiber properties, spinning performance, and yarn property measurements. This report is a summary of the correlations found.

Experimental

Twenty-one (21) domestically grown cottons, representing nine varieties and five different domestic growing areas, from a single season's crop (ranging in HVI micronaire from 3.4 to 4.9) in this study were processed both by rotor and ring spinning. Area of growth is a major factor affecting concentrations of noncellulosic materials in raw cottons (Brushwood and Perkins, 1994). Therefore, to obtain a more comprehensive picture of relationships, area of growth summations were used.

Six cottons originated from the Western U.S. (California and Arizona), five from the High Plains of Texas (Southwestern) four from the Central states (Arkansas, Missouri, and Tennessee), four from the Midsouth (Louisiana and Mississippi) and two from the Southeast (South Carolina and Georgia). Average micronaire determined by growing area ranged 3.90 for Southwestern to a high of 4.6 for Central cottons.

Each raw cotton was conditioned in our laboratory for at least three weeks before moisture (ASTM method D2495-01), sugar, wax, and alcohol extractable contents were determined on each. Triplicate fiber moisture contents for the cottons ranged from 6.66 to 7.28 percent with no significant difference between variety or location. Individual fiber moisture contents were used in determining sugar, wax, alcohol extractables, and metal contents.

Waxes and total alcohol extractable materials were determined by six hour soxhlet extractions of 2.5 gram samples (1-1-1 tricholoethane solvent for the wax and 95% ethanol for total extractables) of each cotton. Resultant wax and alcohol extractable contents were averaged from a total of 24 extractions per cotton. Sugars (in triplicate) were determined by the USDA potassium ferrocyanide (Perkins) reducing sugar test. Metal contents (triplicate samples) were determined by atomic absorption spectroscopy using a Buck 200 instrument as specified in a previous study (Brushwood and Perkins, 1994).

HVI measurements for these cottons were conducted by the USDA classing office in Memphis, TN. Stelometer strengths, Suter-Webb short fiber contents, and AFIS neps were determined by the USDA Testing Laboratory in Clemson, SC.

Raw fiber RotorRing friction tests were conducted by the Institute of Textile Technology (ITT) in Charlottesville, VA. Fiber to metal (f/m) and fiber to fiber (f/f) values for each cotton were reported in the energy units of joules (Ghosh, et al, 1992). At least four replicate measurements per test were conducted on each cotton and the results averaged.

Rotor yarn size of 10, 22, and 30 Ne and ring yarn size of 22, 36, and 50 Ne were produced for each cotton. Production data for individual fibers include yarn skein break factor, elongation, single end yarn strength, yarn evenness, ends down, and opening/carding waste. Growing area summaries in the accompanying Tables 1 - 4 are the combined averages for each yarn count.

Area of growth yarn break factor and elongation for rotor and ring spun yarns are summarized in Table l. Ring spun 22 Ne yarn had an average break factor that was 14 percent higher and slightly lower in elongation than rotor spun 22 Ne yarn. Western cottons averaged 15 to 20 percent higher yarn break factor than the other growing areas.

Single end yarn strength test results are shown in Table 2. Ring spun Ne single end yarn strength averaged 26 percent higher than the same size rotor yarn and, as with yarn break factor, Western grown single end yarn strengths were consistently higher than other areas.

A summary of evenness thick, thin, and nep IPI defects for both spinning systems are listed in Table 3. Southwestern (Texas) cotton ring yarn thick and thin places averaged 13 and 20 percent higher than other growing areas, respectively. Cottons originating from the Central U.S. growing area produced more rotor-spun evenness thick and thin places than other growing areas and the Western grown cottons averaged fewer thick and thin places in both spinning systems.

Ends down in spinning and opening carding waste (Table 4) ranged from a high of 170.9/1000hrs. and 7.73%, respectively, for Southwestern to a low of 41.6/1000hrs. and 6.57% in Western cottons

Results and Discussion

Chemical Analysis

Reducing sugars ranged from 0.21 to 0.61 percent with slightly higher average concentrations found on Western (0.47%) and Southwestern (0.35%) grown cottons. Wax content ranged from 0.34 to 0.52% with the five Southwestern growing area cottons averaging a high of 0.45% and the Central a low of 0.40%. No significant differences in either sugar or wax concentration were seen between varieties.

Alcohol extractable materials ranged from 1.11 to 2.11 percent. In general, those cottons yielding higher levels of alcohol extractions correlated well with increasing reducing sugar levels. The coefficient of simple correlation (r) for all 21 cottons was 0.80. Individual ash residue produced prior to determination of metals ranged from 1.00 to 2.11 percent. Western cottons averaged a high of 1.68 and Midsouth a low of 1.22 percent. Positive correlations were found between alcohol extractables and ash residues (r = 0.80) for all 21 samples. Table 5 is a summary of sugar, wax, total alcohol extractables, and ash residues averaged by growing areas.

Metals

Potassium concentrations (Table 6) ranged from just below 0.3% (2960 ppm) to nearly 0.7% (6960 ppm), calcium from 570 to 1225 ppm, and magnesium from 312 to 740 ppm for all 21 samples. The western cottons averaged about 30% higher levels of potassium and 20% higher levels of magnesium other growing areas. Southwestern cottons averaged at least 20% higher calcium content than other growing areas. Total light metal contents including the metal sodium ranged form as low as 0.41% (based on the dry fiber weight) for a single Mississippi DP50 cotton to a high of 0.90% on a single California SJ2 cotton.

Fiber-Friction Measurements
RotorRing f/m and f/f friction averages (table 6.) ranged from 7600 to 15900 joules for f/m and 17400 to 24000 joules for f/f measurements. Cottons originating from the Western (California and Arizona) and Southwestern (Texas) growing areas had higher f/m frictional properties. Average RotorRing f/f frictions ranged from 18205 joules for Central to a high of 21950 joules for Western grown cottons.

Relationships between Extractables, Metal, Ash Residue, and Fiber Properties
Correlations (r values) obtained from averaging by growing areas are shown in Table 7. Wax, reducing sugar, alcohol extractables, ash residue, and total light metal concentrations were found to be micronaire dependent. As micronaire increased, their concentrations tended to decrease. There was a significant correlation between wax content and micronaire (r = - 0.90). As the fiber micronaire, increased wax concentrations decreased.

HVI and Stelometer strength measurements increased as sugar, wax, and alcohol extractables, ash residues, as well as potassium and magnesium content increased. Short fiber content increased as levels of the metal calcium increased. There was a very strong relationship found between fiber magnesium content and HVI +b color measurement (Figure 1.) .

Relationship between Fiber Sugar, Wax, Ash Residues, and Alcohol Extraction Contents and Processing Properties
Table 8 is a summary of the correlations (r values) between yarn skein break factor and elongation, single yarn strength, and evenness measurements and reducing sugar, wax, alcohol extractables and ash residue averages. Positive correlations (Figures 2 and 3) were found between total alcohol extractables and skein break factor and single yarn strength for both rotor and ring spun yarns (r = 0.98 and 0.96, respectively). Skein break factor correlations with alcohol extractables for all 21 cottons were r = 0.65 for rotor and r = 0.68 for ring spun yarns. Alcohol extractable correlations with single yarn strength measurements for all 21 cottons were r = 0.61 and r = 0.65 for rotor and ring spun yarns, respectively. Evenness thick and thin places increased and ring neps decreased as alcohol extractables increased.

Reducing sugars, and to a lesser degree, wax levels and ash residue followed the same general pattern observed with the alcohol extractables. As levels of all three increased, skein break factor, single yarn strength, and ring evenness neps also increased. Increased reducing sugar, wax, and ash residue correlated with decreases in both rotor and ring yarn thick and thin places. Most noteworthy is the decrease in measured rotor spinning thick and thin places. (r = - 0.95 and r = - 0.94, respectively) as fiber surfaces wax increases (Figure 4). Rotor evenness neps tended to decrease as concentrations of reducing sugars, waxes, and ash residues increased.

Fiber Light Metal Contents and Friction Measurements
The light metals potassium, calcium, and magnesium accounted for an average of about 40 percent of ash residue. There was, however, a very positive correlation found between ash residue and total potassium, calcium, and magnesium content (r = 0.91, n = 21, and r = 0.95 when averaged by growing area). The correlation values between potassium, calcium, magnesium, and total potassium, calcium, and magnesium contents, and f/m and f/f RotorRing friction measurements and processing skein break factor and elongation, single yarn strength, and evenness measurements are shown in table 9. Individually, as the metals potassium and magnesium increased (Figures 5 and 6), yarn skein break factor and single yarn strength increased and evenness thick and thin places decreased. Conversely, increases in calcium content related to decreases in both break factor and single yarn strength and increases in evenness thick and thin places in ring spinning.

Fiber to metal and fiber to fiber RotorRing friction measurements that are positively related to both alcohol extractable (r = 0.70 and r = 0.86, respectively) and ash residue (r = 0.71 and r = 0.55, respectively) show positive correlations with both break factor and single yarn strength. This is particularly true of the f/f friction measurement. Correlations with ring break factors and single yarn strengths (Figure 7) were identical at r = 0.95. Slightly lower correlations between f/f friction and rotor yarn break factors and single yarn strengths were r = 0.89 and r = 0.81, respectively.

Ring evenness neps were very positively related to potassium, magnesium, total light metal content, and f/m friction. However, rotor evenness neps decreased as the above metals and friction energies increased.

Ends Down and Opening/Carding Waste
Correlation coefficients between all extractable materials, metal contents, and friction measurements and ends down in spinning and opening/carding waste were determined. Statistically, as RotorRing f/m friction increased, ends down in spinning were found to decrease (r = - 0.66). Opening and carding waste residue was positively related to fiber calcium content (r = 0.86). As levels of calcium increased, opening and carding waste also increased. Increases in the fiber potassium content

tended to correlate with decreases in opening and carding waste (r = - 0.71). Since f/f friction is very positively related to the potassium content, increases in f/f friction also correlated with decreasing opening and carding waste (r = - 0.93).

Summary and Conclusions

A series of domestically grown cottons consisting of nine varieties from five different growing areas were analyzed for surface reducing sugar, wax, total surface extractables, fiber ash residue, light metal content, and frictional properties. Determined values were subsequently correlated to raw fiber physical properties, rotor and ring spinning performance data and the subsequent properties of the produced yarn. No significant varietal effects on these measurements were detected. Area of growth, however; had a strong influence.

When correlated with fiber physical property measurements, there were very positive correlations found between the amount of solvent extractable noncellulosic materials, the metals potassium and magnesium, and ash residues and fiber strength measurements. As extractable materials increased, fiber strength increased. Wax concentrations on the fiber increased as micronaire decreased. Higher levels of the metals potassium and magnesium in the fiber tend to reduce the short fiber measurements. Also, increased levels of potassium and magnesium are related to increases in HVI Rd and +b color measurements.

Rotor and ring yarn break factor and single yarn strength measurements for all 21 cottons correlated very positively with the amount of ethyl alcohol extractable materials removed from the fiber. When averaged by growing area, the simple coefficient of correlation between alcohol extractables and skein break factor and single yarn strength for both spinning systems were identical at r = 0.98 (break factor) and r = 0.96 (single yarn strength). Skein break factor and single yarn strength measurements also showed a tendency to increase as the amount of reducing sugars, wax, and ash residue increased. Evenness thick and thin places decreased, rotor neps decreased, and ring neps increased as reducing sugars, wax, alcohol extractables, and fiber ash residue increased.

Increasing levels of the metals potassium and magnesium correlated with increasing skein break factors and single yarn strengths and lower evenness thick and thin places. Conversely, increasing levels of the metal calcium on the fiber correlated with decreases in yarn skein break and single yarn strength and increases in evenness thick and thin places. Rotor evenness neps decreased and ring neps increased as metal concentrations on the fiber increased.

RotorRing fiber to metal and fiber to fiber friction measurements were positively related to ethyl alcohol extractables and ash residue, therefore; also positively related to yarn strength measurements. Increases in both f/m and f/f friction correlated with increasing ring yarn neps, Rotor evenness thick and thin places and neps all decreased as f/m friction increased. No significant correlations between f/m friction and ring thick and thin places were seen. Decreases in evenness thick and thin places for both spinning systems were highly related to increases in the RotorRing f/f friction measurement.

The ethyl alcohol extraction procedure can be used as a general predictor of how much influence noncellulosics materials may have on fiber and finish yarn quality, however; the contributions of individual constituents like sugar, wax and the different metals is important to know. For example, higher levels of the metal calcium in cottons appears to have a negative effect on overall fiber and yarn strength and may contribute to higher yarn production inconsistency, especially in a ring spinning system. Concentrations of the metals potassium and magnesium also are highly related to increases in HVI, Rd and +b color measurements.

This is a limited collection of U. S. grown cottons that were spun by two different systems. However, even with these samplings, it is clear that noncellulosic materials on cottons have a significant impact on the fiber properties, the yarn manufacturing process, and subsequent yarn quality. Additional research with cottons of different varieties and growing areas would seem worthwhile to verify the findings in this report.

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Table 1. Yarn skein break factors and elongations.

		ROTOR						RING					
		Break Factor			Elongation (%)			Break Factor			Elongation (%)		
LOCATION	**N**	**10s**	**22s**	**30s**	**10s**	**22s**	**30s**	**22s**	**36s**	**50s**	**22s**	**30s**	**50s**
Central, U.S.	4	2076	1709	1545	6.80	6.10	5.68	1988	1755	1450	6.15	5.20	4.98
Midsouth,U.S.	4	2276	1905	1705	7.18	6.38	6.15	2166	2003	1731	6.30	5.62	5.30
Southeast,U. S.	2	2298	1989	1785	7.36	6.44	6.00	2242	2134	1764	6.02	5.34	4.94
Southwest, U.S.	5	2281	1942	1734	6.90	5.90	5.50	2127	1923	1676	5.55	5.00	4.58
West, U.S.	6	2595	2226	1993	7.03	6.28	5.93	2625	2452	2188	6.20	5.73	5.20

Table 2. Summary of single yarn strength measurements for rotor and ring spun yarn – averaged by growing area.

		Rotor (mN/tex)			Ring (mN/tex)		
LOCATION	**N**	**10s**	**22s**	**30s**	**22s**	**36s**	**50s**
Central, U. S.	4	126	112	103	130	114	103
Midsouth, U. S.	4	128	108	103	142	127	123
Southeast, U. S.	2	137	118	109	151	133	123
Southwest, U. S.	5	134	117	108	141	123	116
Western, U. S.	6	149	130	122	174	162	147

Table 3. Summary of Uster Evenness thick and thin places/1000 yards of yarn.

		Rotor Yarn			Ring Yarn		
LOCATION	**N**	**Thick Places**	**Thin Places**	**Neps**	**Thick Places**	**Thin Places**	**Neps**
Central, U. S.	4	103.7	67.3	22.7	2451	1380	772
Midsouth, U. S.	4	73.3	42.7	30.3	2302	1173	788
Southeastern, U.S.	2	48.3	40.7	31.3	2379	1246	837
Southwestern,U.S	5	52.3	23.7	19.7	2763	1682	956
Western, U.S.	6	36.0	23.7	21.7	1979	786	1003

Table 4. Summary of ends down and waste during processing.

LOCATION	**Ring ends down/1000 hours**	**Opening/Carding Waste (%)**
Central, U.S.	106.3	7.47
Midsouth, U. S.	54.4	7.27
Southeastern, U. S.	121.3	6.62
Southwestern, U. S.	170.9	7.73
Western, U. S.	41.6	6.57

Table 5. Summary of average reducing sugar, wax, alcohol extractables, and ash residue for five different domestic growing areas.

LOCATION	**N**	**R.S. (%)**	**Wax (%)**	**Alcohol Extr. (%)**	**Ash (%)**
Central, U. S.	4	0.28	0.40	1.23	1.32
Midsouth, U.S.	4	0.30	0.42	1.35	1.22
Southeast, U. S.	2	0.25	0.44	1.53	1.23
Southwest, U. S.	5	0.35	0.45	1.49	1.38
Western, U. S.	6	0.47	0.44	1.91	1.68

Table 6. Average light metal contents and RotorRing friction measurements for five domestic growing areas.

LOCATION	N	K (ppm)	Ca (ppm)	Mg (ppm)	Friction (joules) f/m	Friction (joules) f/f_
Central, U. S.	4	3820	863	476	9345	18205
Midsouth, U. S.	4	3630	815	439	8463	19563
Southeast, U. S.	2	4380	633	443	10260	20449
Southwest, U. S.	5	4110	1047	489	11952	18284
Western, U. S.	6	5730	783	603	11628	21950

Table 7. Correlations between extractables, ash residue, metal levels and fiber physical properties.

	Str. (g/tex)			SUTER-WEBB		AFIS Neps	Color		Friction (joules)	
	Mic	HVI	Stelo	SFC(%)	/g.	/100 sq in	+b	Rd	f/m	f/f
R.S.(%)	-0.43	0.77	0.53	-0.38	-0.08	0.11	0.77	0.85	0.63	0.56
Wax (%)	-0.90	0.78	0.84	0.16	0.49	0.46	-0.03	0.33	0.78	0.46
Al.Ext(%)	0.47	0.98	0.90	-0.53	-0.10	-0.68	0.64	0.69	0.70	0.86
Ash (%)	-0.37	0.71	0.48	-0.49	-0.11	0.28	0.89	0.70	0.71	0.55
k(ppm)	-0.26	0.88	0.80	-0.66	-0.21	0.41	0.80	0.62	0.66	0.83
Ca(ppm)	-0.43	-0.26	-0.43	0.69	0.65	0.22	0.10	0.04	0.34	-0.65
Mg (ppm)	-0.21	0.71	0.48	-0.53	-0.16	0.25	0.96	0.70	0.65	0.59
K+Ca+Mg(ppm)	-0.36	0.85	0.71	-0.52	-0.09	0.38	0.84	0.65	0.75	0.73

Table 8. Correlations between surface extractables and ash residues and yarn spin performance data.

	SKEIN Break Factor		Elong.(%)		SINGLE Str.(mn/tex)		USTER Th.Places		USTER Tn.Places		USTER neps/1000/yds	
	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring
Sugar (%)	0.80	0.78	0.81	0.66	0.82	0.78	-0.59	-0.50	-0.68	-0.53	-0.61	0.86
Wax (%)	0.74	0.62	0.49	-0.15	0.65	0.60	-0.95	-0.49	-0.94	-0.05	-0.36	0.80
Al.Ext (%)	0.98	0.96	0.52	0.23	0.98	0.96	-0.88	-0.61	-0.77	-0.65	-0.23	0.86
Ash (%)	0.73	0.73	0.63	0.52	0.90	0.74	-0.50	-0.52	-0.52	-0.54	-0.67	0.83

Table 9. Correlations between fiber light metal contents and RotorRing friction and yarn spin performance data.

	SKEIN Break Factor		Elong.(%)		SINGLE Str.(mn/tex)		USTER Th.Places		USTER Tn.Places		USTER neps/1000/yds	
	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring
K (ppm)	0.87	0.86	0.35	0.16	0.99	0.86	-0.75	-0.64	-0.60	-0.67	-0.27	0.80
Ca (ppm)	-0.26	-0.37	0.65	0.36	-0.21	-0.37	0.19	0.63	-0.19	0.63	-0.76	0.27
Mg (ppm)	0.73	0.75	0.60	0.52	0.87	0.76	-0.49	-0.57	-0.50	-0.58	-0.63	0.80
K+Ca+Mg(ppm)	0.87	0.86	0.53	0.25	0.98	0.86	-0.75	-0.52	-0.68	-0.55	-0.48	0.90
f/m Fr(joules)	0.59	0.48	0.57	-0.06	0.74	0.47	-0.70	0.11	-0.75	0.06	-0.65	0.92
f/f Fr.(joules)	0.89	0.95	0.13	0.19	0.81	0.95	-0.71	-0.87	-0.48	-0.90	0.23	0.48

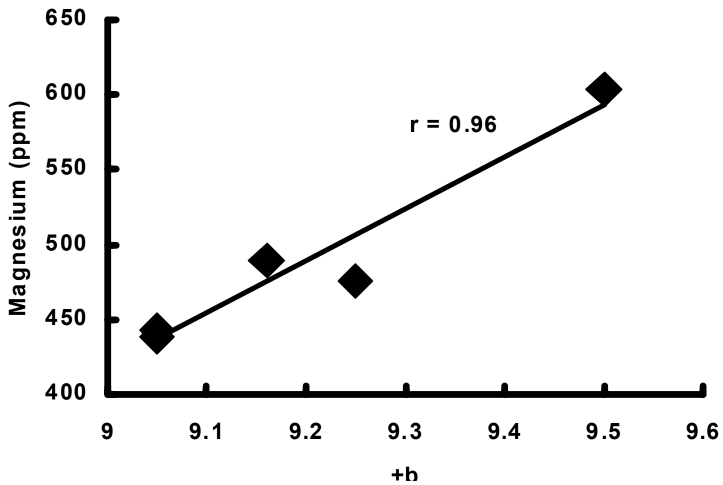

Figure 1. The relationship between magnesium content and HVI color fiber +b value.

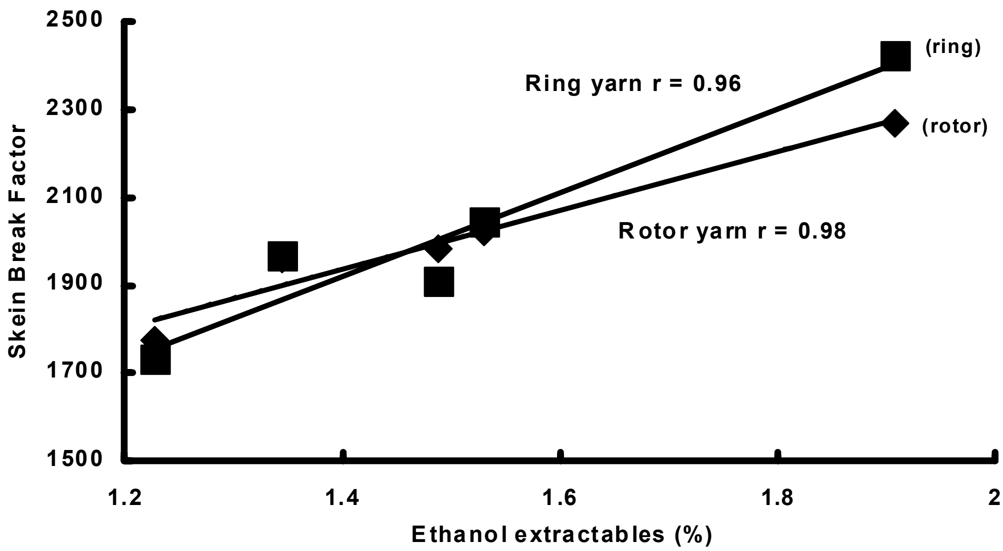

Figure 2. The relationship between ethyl alcohol extractables and yarn skein break factor.

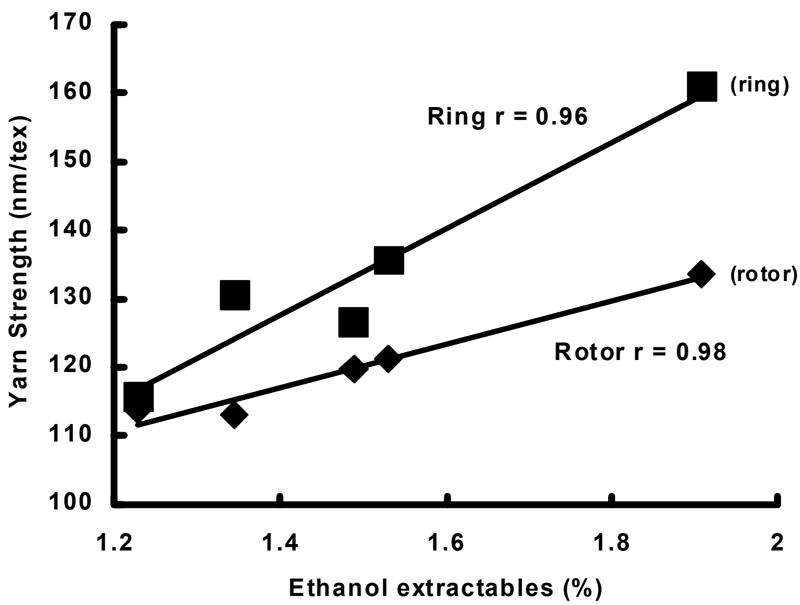

Figure 3. The relationship between ethyl alcohol extractables and single yarn strength.

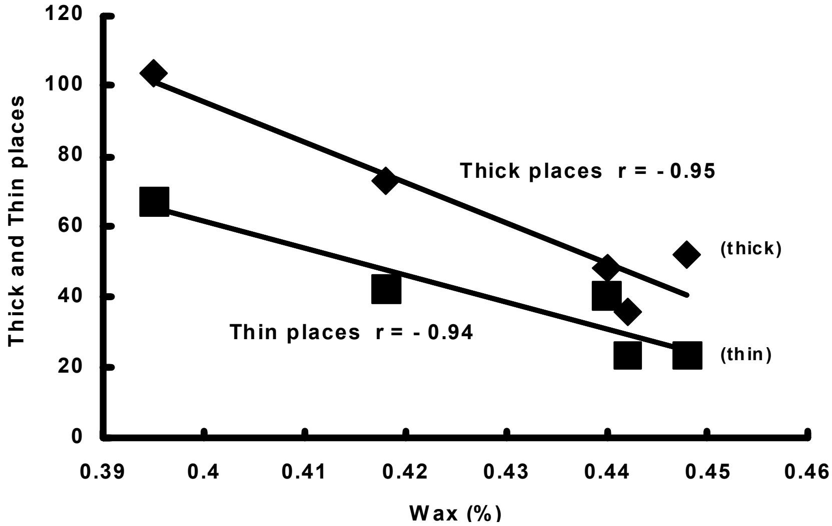

Figure 4. The relationship between wax content and rotor yarn spun evenness thick and thin places.

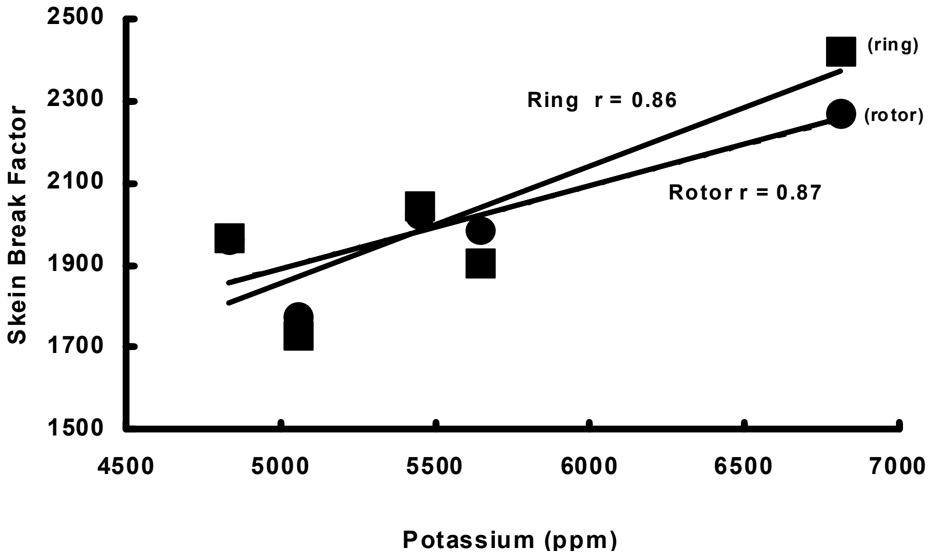

Figure 5. The relationship between potassium content and yarn skein break factor.

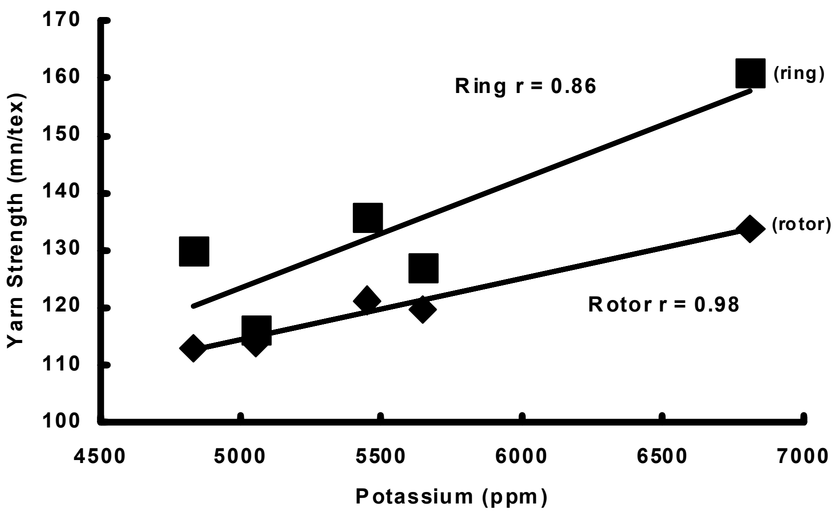

Figure 6. The relationship between potassium content and single end yarn strength.

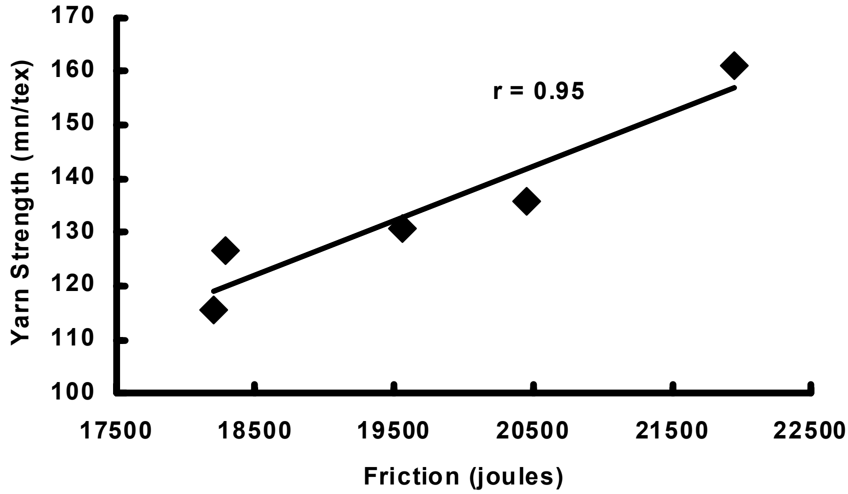

Figure 7. The relationship between fiber to fiber RotorRing friction and Ring Spun single end strength.