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IMPLICATIONS OF PECTIN ON COTTON FIBER PROCESSING

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Abstract

Increasing speeds of cotton yarn production in the textile mill have rendered traditional physical fiber measurements such as length and strength less reliable as predictors of yarn spinning efficiency. With the goal toward addressing this problem, this work attempts to characterize the pectin component of the cotton fiber in order to develop a chemistry-based methodology by which currently unknown factors involved in yarn spinning efficiency may be elucidated. A mathematical relationship of pectin content with fiber micronaire measurements is first established and subsequently used in the comparison of the normalized pectin content with fiber friction measurements. Results indicate that fiber friction decreases as the pectin layer thickness on the cotton fiber outer surface increases. This is an important observation not only from the standpoint of being able to set fiber processing equipment parameters based on chemical measurements, but it also raises the question of whether cotton can be bred in order to produce desirable spinning characteristics based on the level of pectin production during the fiber growth period.

Introduction

In recent years, improvements in cotton yarn production technology have led to great increases in production rates. One consequence of these improvements is that the standard high volume instrumentation (HVI) measurements of fiber properties such as length, strength, and uniformity are no longer able to satisfactorily predict yarn-spinning efficiency (El Mogahzy et al. 1997). Spinning performance is affected by the surface characteristics of cotton fibers (El Moghazy et al. 1998). Several factors contribute to the surface frictional forces between fibers, including fiber morphology (convolutions), geometric features (length, fineness), and static electrical forces. In addition, the surface of the fiber is comprised of a primary cell wall composed chiefly of pectin and hemicellulose and a cuticle composed of waxes. Since these outer surface components are in direct contact with neighboring fibers, their physical dimension and chemical compositions may have a much larger impact upon spinning performance than is reflected by their low overall abundance relative to cellulose. Increased wax content has been correlated with decreased fiber-fiber and fiber-metal friction as determined by the modified rotor ring energy (El Mogahzy et al. 1998). Similarly, an increased quantity of calcium present in the fiber has also been correlated with decreased fiber-fiber and fiber-metal friction (Brushwood, unpublished results). Calcium in cotton fiber is associated with the primary cell wall, where it serves to cross-link pectin polymers. Increased pectin content is thus indirectly correlated with decreasing fiber friction.

In order to elucidate some of the factors involved in spinning performance, it is necessary to further characterize the surface chemical constituents of cotton. Surface frictional properties are likely to be directly correlated with quantities of surface chemical constituents. One factor affecting the quantity of pectins and waxes relative to the whole fiber is maturity. Maturity is a function of the proportion of secondary cell wall relative to the fiber perimeter. Micronaire effectively measures the degree to which the secondary cell wall has been established and is thus used as a measure of maturity. The secondary cell wall is comprised nearly exclusively of cellulose and accounts for approximately 95% (w/w) of the raw cotton fiber. Because growth of the secondary wall is initiated following the establishment of the primary cell wall and cuticle, the proportions of chemical components comprising the primary cell wall and the cuticle are expected to decrease as the fiber matures and the micronaire value increases. This has been observed (Cui et al. 2002) in the case of wax, and it is thus reasonable to assume that surface chemical components associated with the primary cell wall will also have some dependence upon micronaire. Quantities of a surface component falling above or below the average value expected at a given micronaire value may indicate a change in layer thickness (or density) potentially affecting frictional properties. The purpose of this work is to examine the quantitative dependence of pectin upon micronaire, and subsequently use this relationship to evaluate the effect of pectin differences upon spinning performance as measured by a variety of methods.

Materials and Methods

For this study, a total of 87 cotton samples exhibiting a wide range of genetic diversity, micronaire, growing regions, and storage times were chosen.

Micronaire was measured by high volume instrumentation (HVI) according to standard test methods (ASTM 1997).

Cotton fiber pectin content was determined by enzymatic degradation and subsequent analysis of galacturonic acid, the primary byproduct of enzymatic degradation. Enzyme treatments of cotton samples consisted of adding 10µL of pectinase (Sigma Chemical Co.) to a 0.10 g cotton sample in 10 ml of a pH = 4.0 buffer solution. To this suspension was added 0.01 g

EDTA, with subsequent heating at 50°C for 18 hours. For galacturonic acid analysis, high performance anion exchange chromatography (HPAEC) was performed on the resultant suspensions with a Dionex DX-500 using pulsed amperometric detection and two Dionex Carbopac PA-1 (4 x 250 mm) columns connected in series. Elution was carried out at 0.75 ml/min using 200 mM NaOH as the mobile phase and a sigmoidal gradient of 0 to 500 mM NaOAc. Galacturonic acid content is reported as the fraction (w/w) present on the fiber.

Slivers from a subset of the 87 cotton samples were evaluated for drafting force. The drafting force, measured in pounds, is a measure of the force required to parallelize the assembled fibers. The measurement was determined by deflection of one pair of rollers in a two pair draft zone, and was calibrated using weights to determine the force required to cause a given deflection of the roller pair.

The same subset of cotton samples were evaluated for fiber-fiber and fiber-metal friction using the rotor-ring system at the Institute for Textile Technology, Charlottesville, VA. Results are reported in Joules (J).

Results and Discussion

A diagrammatic representation of a cotton fiber cross-section is shown in Figure 1. Previous research (Meinert and Delmer 1977) has shown that the primary wall is formed prior to the deposition of the secondary wall (with some overlap in growth periods) and that once formed does not degrade, but remains constant. Even though the fiber diameter may change (Seagull et al. 2000), the cross-sectional area of the primary wall, described by A_P, probably does not change except in cases of environmental or microbial damage. A_T describes the cross-sectional area of the fiber due to all components including the primary and secondary cell walls. Assuming that A_P is constant and that A_T is proportional to the micronaire value, then the relation $A_P/A_T = x$ becomes $b/x = M$, where M=micronaire. This model describes the situation where the pectin component is constant while the secondary wall is formed. The two constraints (1) x approaches 1 as A_T approaches A_P and (2) A_T approaches infinity as x approaches 0, are in keeping with observation. Figure 2 shows a comparison of galacturonic acid content with micronaire for the entire set of 87 cotton samples. The curve $M = b/x$ with $b = 0.022$, approximates the boundary describing the minimum amount of galacturonic acid as a function of micronaire. Those points falling to the left of the curve have lower values due to possible microbial degradation, or cavitoma. The cross-sectional area of the pectin layer at the onset of secondary wall growth may vary between samples, however, depending upon a number of potential factors including genetics and environment.

When the galacturonic acid fraction x is multiplied by the micronaire value, M, the resultant is the parameter b. If all cottons exhibiting a given micronaire value had the same galacturonic acid content, then b would be constant. As seen in Figure 2, however, galacturonic acid content varies among cotton samples with identical micronaire. The higher the value of the parameter b, the higher the galacturonic acid content, so that b can be considered a measure of the primary cell wall thickness. In order to determine whether the thickness of the primary cell wall has an impact upon the spinning efficiency, the b value for the Textile Variety Trials subset of cotton samples was compared with draft force, as shown in Figure 3. The result of a linear fit, with $R^2 = 0.47$, indicates that as b increases, the drafting force decreases, implying that the primary cell wall in some way acts as a lubricant. Results from a comparison of the parameter b with fiber-fiber friction as measured by the rotor-ring, shown in Figure 4, show a similar implication; friction decreases as the primary cell wall thickness increases, though the coefficient of multiple determination, $R^2 = 0.40$, is not as strong as in the case of the draft force measurement. These results are further corroborated by comparison of the parameter b with fiber-metal friction, shown in Figure 5, though the coefficient of multiple determination, $R^2 = 0.24$, is substantially smaller than in the case of the draft force measurement.

The observation that cotton fiber friction is affected by the thickness of the pectin layer is important in that it may enable operators to set fiber processing equipment parameters to optimal levels based on the chemical measurement of pectin content in conjunction with micronaire. The results presented also raise the question of whether cotton breeders can develop varieties in order to produce desirable spinning characteristics based on the level of pectin production during the fiber growth period, a factor presumably controlled by genetics.

References

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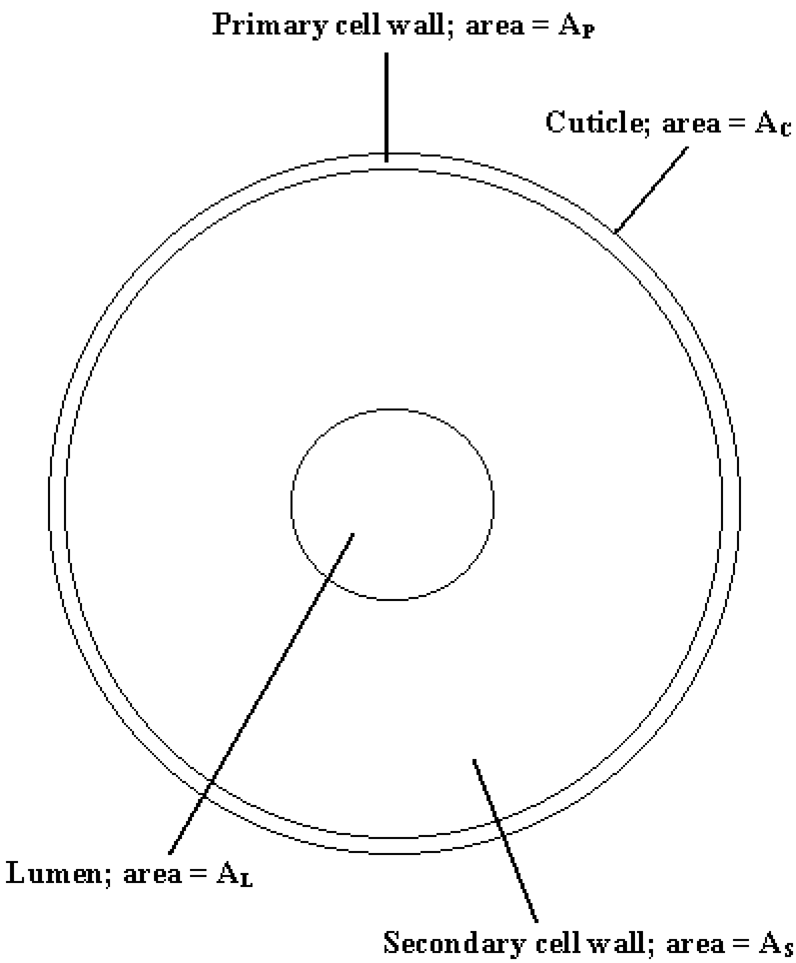

Figure 1. Diagramatic representation of cotton fiber cross section.

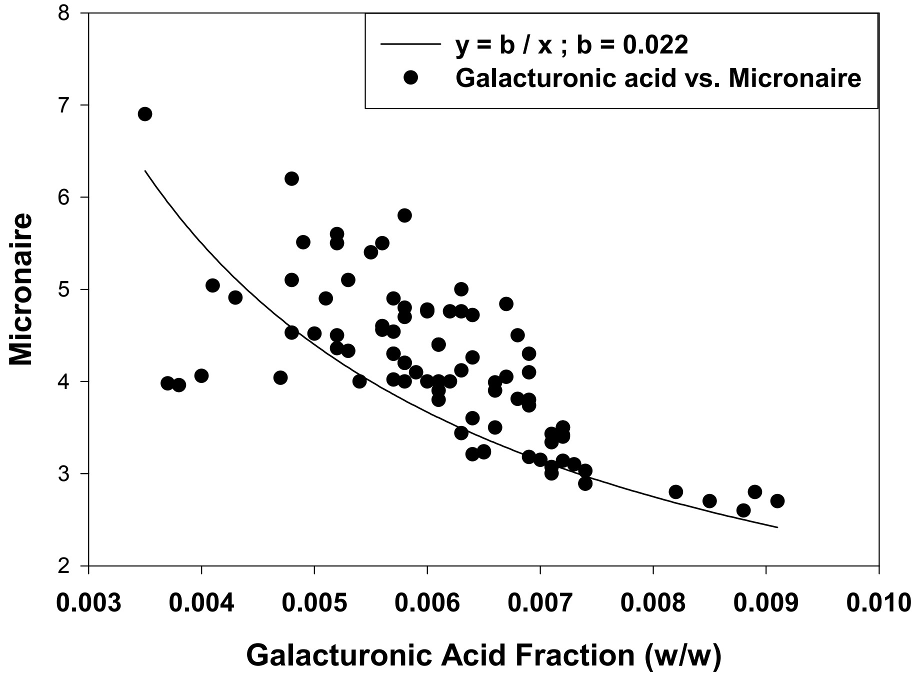

Figure 2. Comparison of galacturonic acid fraction with micronaire.

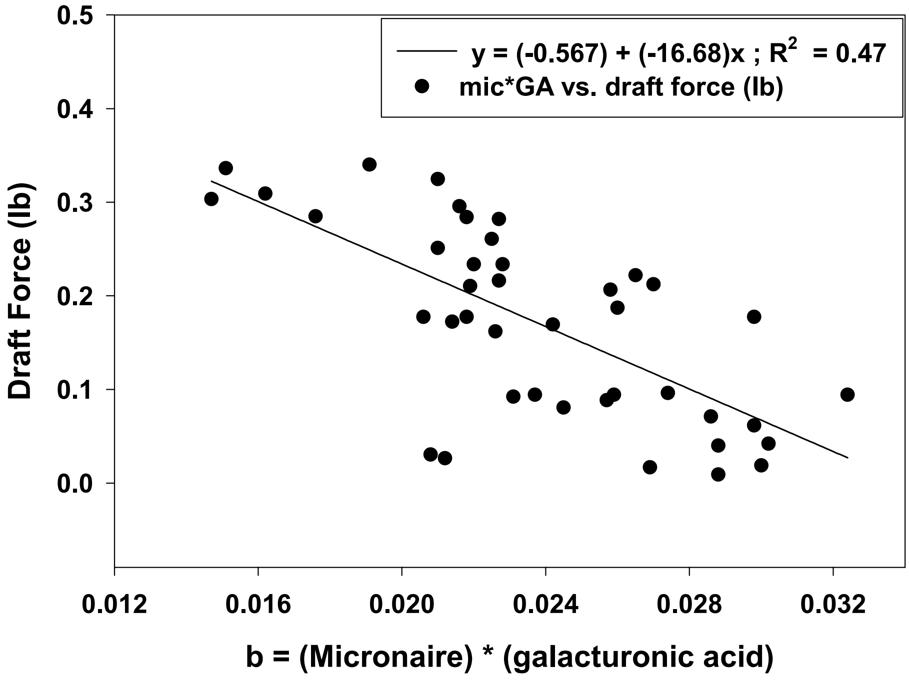

Figure 3. Comparison of parameter b with delta force.

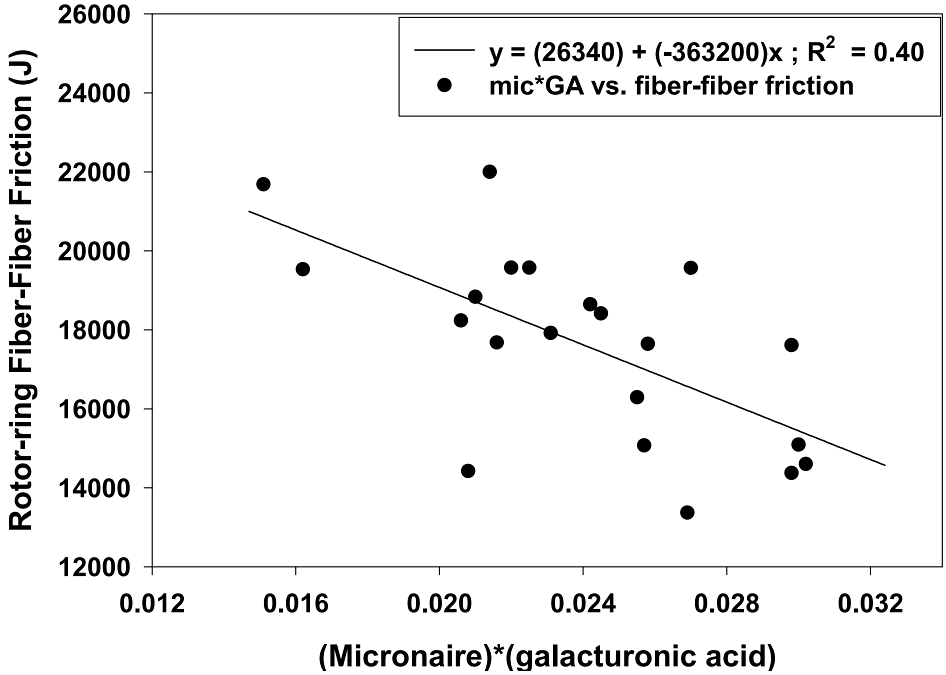

Figure 4. Comparison of parameter b with fiber-fiber friction as measured by roto-ring.

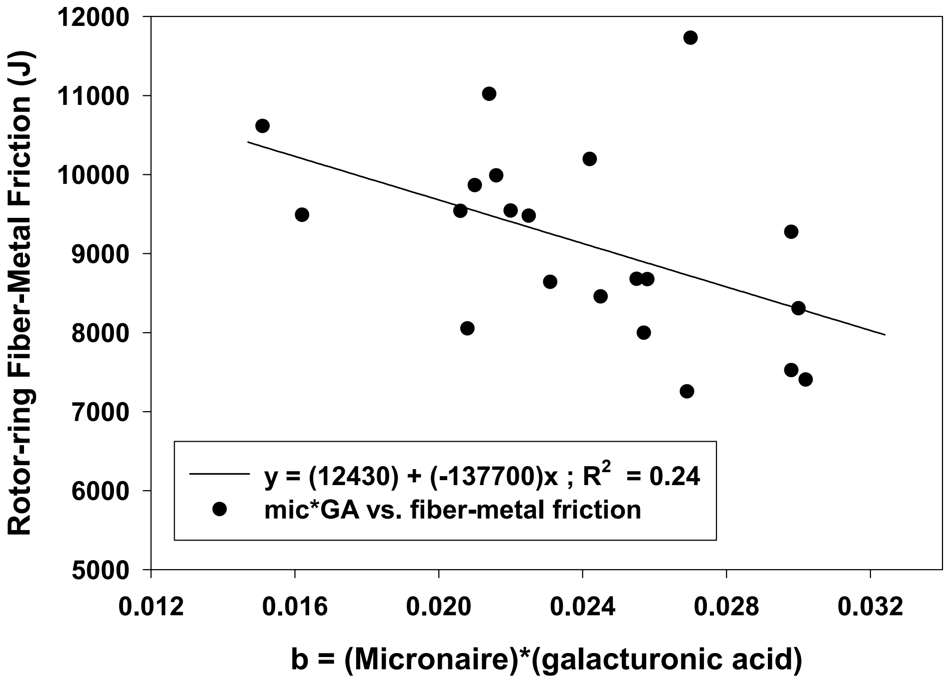

Figure 5. Comparison of parameter b with fiber-metal friction as measured by roto-ring.