THE DETECTION OF COTTON IDENTITY THEFT: FIBER EVALUATION

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Abstract

Cotton identity theft is the case when a product is claimed to be made of a highly appealing fibers to consumers, like Egyptian or Supima cottons, while it is actually made from other lower quality cottons or blends of high and low quality cotton varieties. One way to detect cotton identity theft is evaluating the properties of fibers extracted from the end product and comparing them with a database of different cotton fibers. Evaluation of cotton fiber properties from bale or after an intermediate spinning process is commonly and successfully made using fiber testing machines like Uster® HVI or AFIS. In case of having cotton yarn or fabric or a finished end product, the use of these machines is impossible. Evaluation of the properties of fibers extracted from yarns is often done manually. This incorporates a great deal of variability in addition to tediousness. This paper introduces two promising unconventional ways to detect cotton fiber identity: Viscosity of a 0.5% cellulosic solution, and sonic modulus of fabrics, yarns, or fibers. These methods have never been used for cotton fiber identification. The results show that these two methods can detect distinguished differences between different cotton types if tested in a fabric or yarn forms. Building a good and inclusive database is a key factor for the success of the detection of fiber identity theft.

Introduction

This paper is a part of our effort to detect the cotton identity theft starting with our conceptual paper published in this same proceedings, Elmogahzy, Farag and Celikbag (2010). Our preliminary investigation on many cotton fibers from different sources allover the world showed that viscosity increases with the increase of fiber length, Micronair, maturity, and decrease in immature fiber content. On the other hand, viscosity increases substantially with the increase in the Rd and decrease in the +b. Sonic modulus was found to be related to fiber type as well as yarn and fabric structures.

The Objectives of this paper is to present and test the feasibility of two easy methods to detect cotton identity theft:
(1) viscosity of 0.5% cellulosic solution of a shredded piece of the suspected fabric or yarn extracted from it,
(2) sonic modulus of the fabric or yarn extracted from it.
Both methods expected to be fast and easy to use. The correct interpretation of the results of these tests will lie solely on the inclusiveness and correctness of a good database.

Materials and Methods

Materials in this work are raw cotton fibers of different types and origins available to us as well as yarns and fabrics made of known cottons or cotton mixes. Raw fibers will be used to examine the difference between them in their raw form. Yarns from bobbins and yarns extracted from fabrics will be also used to trace the extent of fiber properties in the yarn and the opposite. At the end, we will present a case study where we have two different fabrics of known materials and apply the proposed methods and acquired information on them to test these methods ability of detecting cotton identity theft.

Viscosity

In definition, dynamic viscosity is the ratio between the shear stress and the shear rate that takes place whenever a liquid flows. Therefore, the units of viscosity are units of stress divided by the units of speed: (dyne.sec/cm^2) or centipoises. It might be useful to know that water at 20 °C has a viscosity of almost one centipoise. The more the liquid resists the tendency to flow, the higher its viscosity. Dynamic viscosity is kinematic viscosity multiplied by the density of the fluid. Capillary viscometers are special glass U-shaped tubes with bulbs used to indirectly measure the viscosity of a fluid under certain conditions. The time the fluid takes to run certain passage through the tube is proportional to the solution viscosity. Tubes are calibrated by standard fluids of known properties. Each tube is assigned a tube constant.

*Viscosity (*centipoises) = *tube constant* * *fluid density* (g/cm3) * *efflux time* (seconds*)*

Measurement of viscosity is one of the many methods known for determining degree of polymerization DP. The relation between viscosity and DP is governed by Mark-Houwink equation:

$$Viscosity = k*(Molecular\ weight)^{a}$$

where *k* and *a* are constants for a specific polymer/solvent/temperature combination found empirically.

Establishing the above relation for a certain polymer solution, viscosity can be used in the assessment of damage in textiles, Qinguo Fan (2005). Schwenker and Whitwell (1953) used the change in DP as a measure of the degradation of cellulosic regenerated fibers during mechanical processing. Same principle was used by Bhujang and Nanjundayya (1955) for the assessment of the degradation of cotton during processing. Same way, solution viscosity of a pulp gives an estimation of the average degree of polymerization of the cellulose that indicates the relative degradation of cellulose fiber during pulping /bleaching process, Mark et al (2002).

In this work, we adopted TAPPI-T230 om-89 for measuring viscosity of pulp by capillary viscometer method. More vagarious and longer time were needed for dissolving raw cotton fibers. This test method is for measuring the viscosity of 0.5% cellulosic solutions. An amount of clean cotton fibers equivalent to 0.25 grams of moisture free material is dissolved in a 25 cc of 0.5M Cupriethylenediamine and a 25 cc of water. A capillary viscometer is used to measure the viscosity of the solution. This solution density is equal to 1.052 g/cm^3. Raw cotton was treated with hexane and alcohol to remove the natural waxes before making the cellulosic solutions.

Sonic Modulus

The Sonic modulus or the dynamic elastic modulus is calculated from the speed of a sonic wave measured when propagating through the material. Measurement of sound velocity can provide much insight into the physical and chemical structure of materials. Aly El-Sheikh (1974) found that both dynamic elastic modulus and initial modulus increase with the increase in the polyester percent in a yarn made of Viscose/polyester blend. Dynamic modulus increased with the increase in yarn tension when measuring the sonic wave speed. Woo and Postle (1978) used the dynamic elastic modulus to predict cotton fiber maturity. Despite the high variability between individual measurements, they found the correlation between the sonic modulus and cotton maturity significant. Blyth and Postle (1979) stated that the sonic modulus of a fabric is one of the most important properties of a fabric that needs more attention as it is nondestructive and easy to measure. Bending and fabric shear can also be predicted using this method. Ryan and Postle (1981) used sonic modulus to predict the configuration of fibers in yarns and fabrics. Hussain et al (1984) found a high correlation between sonic modulus and recovery parameters as well as the yarn breaking extension of mercerized and cross linked cotton yarns. Farag et al (2006) used the sonic modulus to evaluate the orientation in extruded cellulose fibers.

A sonic wave transmitter transducer and a receiver transducer were put at different distances on the material. The differences between times (Δt) and differences between gauges (Δl) were used to calculate the speed of the sonic signal. Sonic modulus is proportional to the square of the sonic wave speed.

$$E = \rho . C2$$

where:

- *E* – Sonic modulus of elasticity (G Pa)
- *C* – speed of sound (km/sec)
- *ρ* – density in (gram/cm3)

For fibers, yarns or fabrics, considering the relation between material density and linear density, sonic modulus can be calculated in grams per denier as follows:

$$E = 11.3*C2$$

where:

- *E* – Sonic modulus of elasticity (g/denier)
- *C* – speed of sound (km/sec)

Results and Discussions

Viscosity Results and Discussions

Results of measuring the viscosity of raw cotton fibers 0.5 % solutions vs. HVI fiber strength is shown in Figure 1. It is obvious that, in most cases, the stronger the fiber the higher the viscosity value. This testifies for the possibility of using the viscosity of a solution made the same way from a cotton end product to tell about the used cotton type. Figure 2 shows the viscosity of pima/upland blends made of raw cottons as well as scoured and bleached cottons. Scouring and bleaching were made to simulate the wet processing most of the cotton products has to go through. Raw cottons show higher viscosity values than the bleached cottons. This is expected due to the negative effect of bleaching on cotton.

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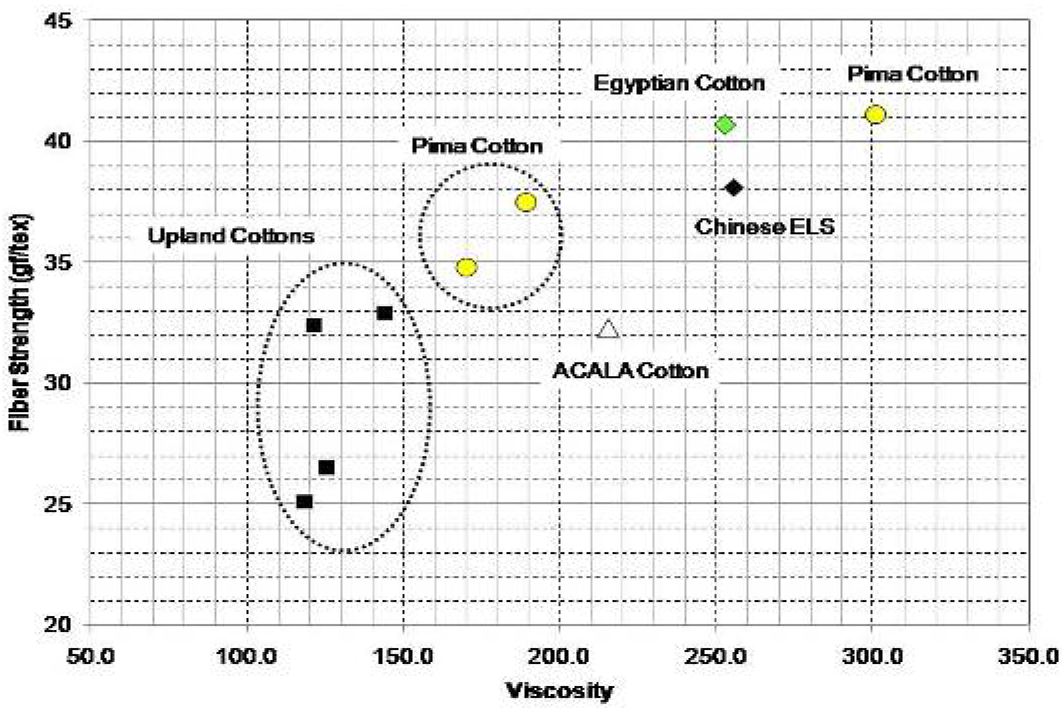

Figure 1. The relation between cotton fiber viscosity and strength

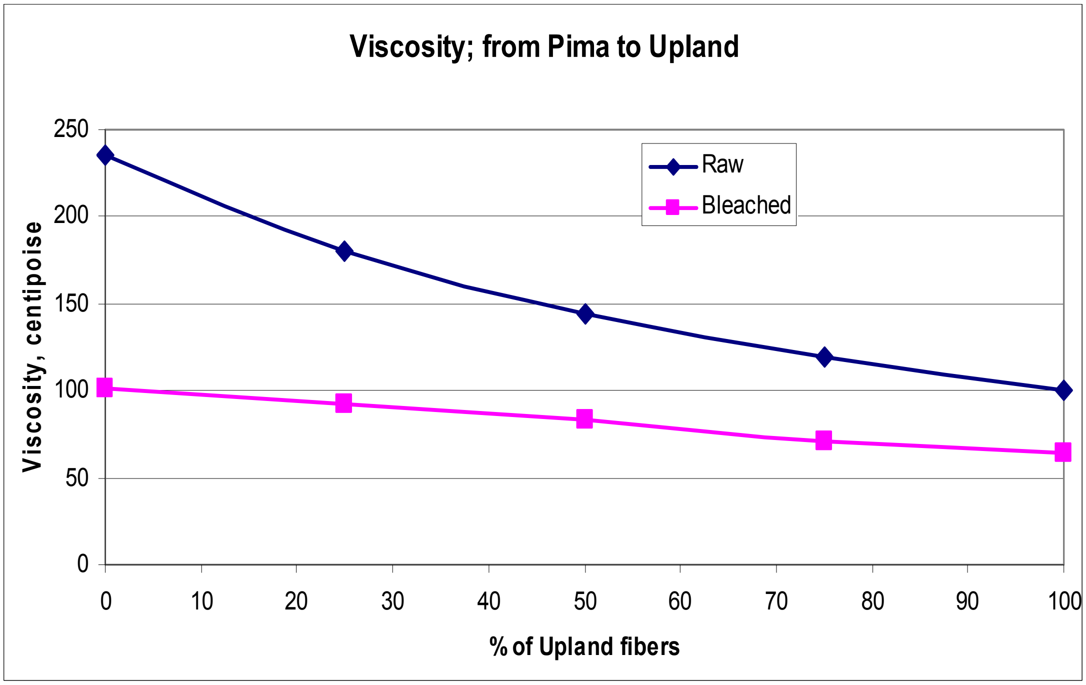

Figure 2. Viscosity of cotton fiber blends, raw and bleached

Sonic Modulus Results and Discussions

In this work, we used the Dynamic Modulus Tester PPM-5R® from Lawson and Hemphill Inc. When measuring fibers and yarns, we used tension values of 0.25 to 0.50 g/tex. Fabric pieces were laid down relaxed. Table 1 shows the sonic speeds and sonic modulii measured for raw cotton fibers. Note that we provided multiple categories within Upland and Pima cottons. This shows the challenge assessment faces due to the overlap between cotton categories.

Table 1. Sonic speed and sonic modilii for different raw cotton fibers

Cotton Fibers	Speed, km/sec	Sonic E, g/denier
Upland-1	0.61	4.26
Upland-2	0.74	6.20
Upland-3	0.89	8.95
Pima-1	0.84	7.97
Pima-2	1.04	12.22
Pima-3	1.25	17.66
GIZA 70	0.86	8.40
CHINESE	1.07	12.86

Figure 3 shows sonic speed measured in yarns from different Pima and Upland cottons. These yarns are taken from bobbins, i.e. no chemically treated yet. After chemical treatment, the values expected to be lower without changing the rank of fibers. It is useful to mention here that measuring the sonic speed for yarns is much easier and results more consistent than that for cotton fibers. Therefore, it can be considered a great success if testing yarns will reveal the type of cotton instead of testing the fibers. Also, yarns can be extracted easily from fabrics compared to fiber extraction from yarns.

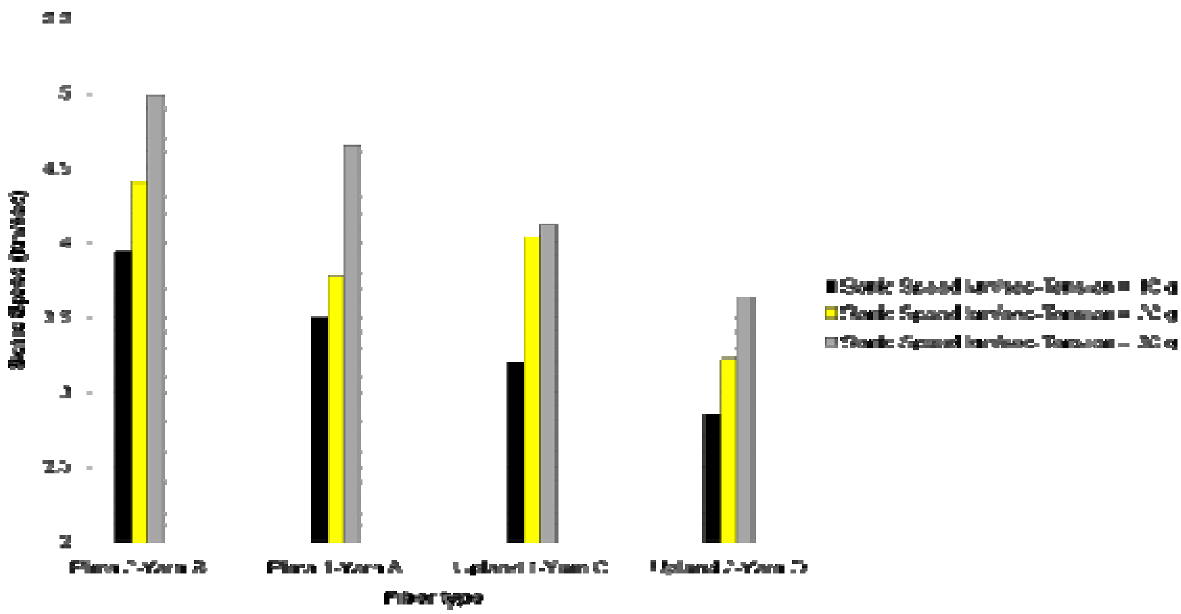

Figure 3. Sonic speed values for four yarn samples made from Pima and Upland cottons

Case Study

For this case study, we used two similar single jersey cotton knit fabrics, one made out of ELS cotton where the other one is made out of medium-long cotton. Specimens for viscosity measurements were prepared from yarns extracted from the fabrics in two different ways; (1) fibers were extracted after untwisting the yarns on a twist tester, (2) yarns were cut into short pieces less than one mm long. For the sonic modulus test, fabrics were measured in both wales and course directions. Yarns extracted from the fabrics were also tested for the sonic modulus

Table 2. Vicosity of 0.5% cellulosic solutions prepared from fabrics of different cotton types

Material	Viscosity
Fbric#1 (Pima)	36
Fbric#2 (Upland)	24

Table 3. Sonic speed and sonic modilii for yarns and fabrics made of different cotton types

Material	Speed, km/sec	sonic E, g/denier
Yarn from knit fabric, Upland	1.46	24.219
Yarn from knit fabric, Pima	3.08	107.405
Knit fabric, Wales direction, Upland	0.14	0.219
Knit fabric, Wales direction, Pima	0.15	0.260
Knit fabric, Courses direction, Upland	0.03	0.013
Knit fabric, Courses direction, Pima	0.04	0.014

These results show that either viscosity or sonic modulus is able to detect the difference between the tow fiber types. For Pima fibers, viscosity and sonic modulus are always higher than those for Upland cotton.

Conclusion

Viscosity test seems to be very useful in distinguishing one type of cotton from another. Sonic Test shows differences between cotton yarns of different types based on their molecular orientation. For both methods, more data need to be generated for raw cotton fibers as well as fibers extracted from fabrics. An inclusive database is the key to successful cotton fiber identity theft detection.

Acknowledgements

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