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Evaluation of Cotton Fibers Stickiness by Colorimetric Method

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ABSTRACT

The stickiness of cotton fiber is a problem in textile spinning process due to contaminated lint adhering to equipment. The degree of stickiness depends on chemical identity, quantity, and distribution of the sugars. The sugar in cotton fibers may be insect- or plant-derived sugar. There are several methods for measuring cotton fibers stickiness. In this work, a colorimetric method is used for the measurements. In the proposed method, honeydew is caramelized by heating cotton fibers, which caused the color of the honeydew to change from pale/colorless to yellow and brown. Heating did not cause any discoloration or change in cotton fibers. Then the yellow index (+b) is used for determining the cotton fibers stickiness. There are high correlation and agreement between results of colorimetric, thermodetector and sugar content method. The conformity between colorimetric and sugar content methods is more than the conformity between colorimetric and thermodetector methods. The colorimetric method is a semi-quantitative and high speed method. Prog. Color Colorants Coat. 6(2013), 9-15. © Institute for Color Science and Technology.

1. Introduction

Stickiness occurs when excessive sugars present on fibers are transferred to equipment and interfere with processing. Sugars may be insect- or plant-derived sugar. Cottons contaminated with stickiness cause multiple problems in the spinning mills. These contaminants are mainly sugar deposits produced either by the cotton plant itself (physiological sugars) or by the feeding insects (entomological sugars). The latter is the most common source of contamination. Honeydew, when present in sufficient quantity, is the main source of sugars that can form sticky lint. Honeydew is excreted by certain phloem-feeding insects including such common pests of cotton as aphids and whiteflies. Another source of stickiness is free plant sugars sometimes found in immature fibers. Cotton fiber is mostly cellulose that is formed from sugars synthesized by the plant [1-2]. Dry and mature cotton fibers contain small amounts of free sugars, while immature cotton fibers contain glucose, fructose, sucrose, and other sugars. Less commonly, oils released by crushed seed coat fragments can also result in stickiness. Sugars differ in their stickiness. For example, sucrose, melezitose and trehalulose are all significantly stickier than glucose or fructose when deposited on a fiber. A trehalulose-contaminated fiber is stickier than a

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fiber with an equivalent amount of melezitose [1-2].

Mixtures of sugars, which occur in honeydew, tend to be stickier than single sugars. Locally concentrated sugars, like honeydew, is at higher risk of causing stickiness that more evenly distributed plant sugars [1-2].

Sticky cotton can reduce cotton gin output by up to 25%. At a textile mill, excessive wear and increased maintenance of machinery may occur even when using slightly sticky cotton. In severe instances, mill shutdown with a thorough cleanup is required [3-4].

Once cotton has been identified as being sticky, there are few reliable and cost effective methods available for remediation. The most widely utilized method involves blending sticky bales with non-sticky bales in a ratio of 1:10. Blending can be successful when a small number of bales have been identified as being sticky. One approach to reduce the amount of sugar on the surface of cotton lint involves promoting microbiological activity on the fibers. Under suitable conditions of temperature and moisture, fungal species will grow naturally on cotton consuming the sugars present on the fiber surface. A deleterious side effect of this growth is concomitant degradation of fiber components, including cellulose and pectin, which leads to an unacceptable reduction in fiber quality. A second approach involves the utilization of enzymes such as α-glycosidase to promote hydrolysis of honeydew oligosaccharides to constituent glucose and fructose monomers.

For the sufficient enzyme activity, the moisture in cotton fibers should be 9% or higher. Furthermore, the glucose and fructose result from enzymatic hydrolysis. Subsequent reduction of glucose and fructose levels currently depends on microbial activity and its associated detrimental effects [3-8].

Stickiness from insect contamination has become a worldwide problem for cotton. The degree of stickiness depends on chemical identity, quantity and distribution of the sugars, the ambient conditions during processing (especially humidity) and the machinery itself. Stickiness is therefore difficult to measure. Test method for rapid and accurate measurements of both sugar content and cotton stickiness is needed both for defining and certifying cotton quality and for process control in ginning and textile processing. The sugar content and stickiness of cotton fibers have been measured by several methods such as reducing sugar method, high performance chromatography, minicard method, sticky cotton thermo-detector, high speed stickiness detector and fiber contamination [1, 9].

In stickiness measurement method: The cotton fiber stickiness has been estimated by sticking of contaminated lint to moving parts of machine. In reducing sugar method, reducing-sugar tests based on reduction of the cupric ion has been used to screen for sugar contamination. This method is relatively quick and inexpensive. In HPLC method, the High Performance Liquid Chromatography (HPLC) is used to measure both the reducing and the nonreducing sugars in honeydew. In minicard method, several types of machines are used to measure the physical interaction of all sugars on lint with equipment. One of the methods used in this test is minicard. This method has been replaced as the international standard by the manual thermodetector. The SCT (Sticky Cotton Thermodetector) method measures the physical sticking points transferred to aluminum sheets by a conditioned lint sample that is squeezed and heated. The H2SD (High speed stickiness detector) method is a quicker, automatic version of the thermodetector. In this method, cotton fiber is pressed between a heated and an unheated pressure plate. Sticky points are counted and point size distribution is determined by a computer image processing software. In FCT (the Fiber Contamination Tester), a thin web is fed between two rollers. Then, contamination of the rollers interrupts a laser beam, resulting in a recording [1, 8, 9].

The effect of heating has been examined previously as a method for detecting sugars on cotton lint. This method consists of heating the contaminated cotton for 30-60 minutes at 150 ^{o}C, and subsequently analyzing the caramelized cotton with the Munsel and Nickerson-Hunter color systems [11].

1.1. Color and yellowness

Color results from an interaction between light, object, and the viewer. Color is usually described by three attributes or dimensions such as hue, saturation and lightness. A color space can be used to describe the range of visible or reproducible colors or gamut of a viewer or device. The CIE developed more uniform color space called CIELAB or CIE L*a*b*. Yellowness is defined as an attribute by which an abject is judged to depart from a standard white towards yellow. Yellowness is calculated by a given procedure from the colorimetric or spectrophotometric data, which indicates the degree of deviation of the object color from the colorless or the standard white. The scaling of whiteness and the derivation of whiteness indices are of considerable importance for various industries such as textile, paper, paint, plastics, etc [12-13].

The color of cotton fiber samples is determined from two parameters: degree of reflectance (Rd) and yellowness (+b). The degree of reflectance shows the brightness of the sample and the yellowness depicts the degree of cotton pigmentation. Each color code is represented by a defined area located in a Nickerson-Hunter cotton colorimeter diagram. The b or b* value defines the yellowness-blueness coordinate in certain color space, *e.g*. Hunter L, a, b and CIELAB. The b or b* value is used as the difference between a specimen and a standard reference color. If b or b* value is positive, there is more yellowness than blueness where although b or b*value is negative, more blueness is observed [12, 14].

2. Experimental

2.1. Materials and methods

For this work, thirteen commercial Iranian cotton bales contaminated with broad variety of honeydew were selected on the basis of their sugar content and stickiness. The used materials and devices are Potassium Ferricyanide, tris(1,10-phenanthroline)-iron(II) sulfate, aluminum foil, heater and colorimeter (Indian Star Co.) for measuring the yellow index (+b) of the samples.

The stickiness of each sample was measured using thermodetector, sugar content and colormetric methods. The measurement was repeated 10 times for each sample.

2.2. Thermodetector method

The cotton fiber was spread between two sheets of aluminum foil at a fixed temperature of 90^{o}C for 15 second. The Pressure is briefly exerted on the top of the sheets. Then, the aluminum sheet was removed from the web and the number of sticky points was counted. The results of this method are shown in Table 1 as "Sticky points number".

2.3. Sugar content method

The sugar on cotton fiber was evaluated by using potassium ferricyanide method. In the potassium ferricyanide method (USDA test or the Perkins test), the honeydew content has been measured based on the oxidation of the reducing sugars. Perkins test is one of several methods currently used to screen cotton for potential stickiness. It is a simple, reproducible, and fast method for the quantitative determination of the reducing sugars. The potassium ferricyanide method consists of water extraction of cotton. Then, the water extract of cotton is reacted with the excess potassium ferricyanide in the presence of sodium carbonate. The sugar as a reducing substance in the extract is oxidized by ferricyanide anion. Titration with ceric sulfate dissolved in sulfuric acid solution is used to evaluate the amount of ferrocyanide.

Table 1: The results of sugar content test (Sugar content), thermodetector method (Sticky points number) and colorimetric method (Stickiness index).

No.	Sugar content(%)	Sticky points number	Stickiness index
1	0.080	2.000	1.200
2	0.120	2.100	1.517
3	0.100	2.400	1.400
4	0.188	3.000	1.597
5	0.280	3.000	1.800
6	0.480	5.667	2.400
7	0.480	4.600	2.200
8	0.520	5.667	2.100
9	0.620	4.200	1.967
10	0.680	5.800	2.300
11	0.880	6.667	3.727
12	0.920	7.000	3.077
13	0.960	6.400	3.400

The end point of titration is evaluated by color change from red to faint blue upon oxidation which is shown by tris(1,10-phenanthroline)-iron(II) sulfate. The titration can be calibrated against known quantities of glucose [10-12]. The results of this method are shown in Table 1 as Sugar content.

2.4.Colorimetric method

In this method, each cotton fiber sample was divided in two parts. First part (i.e. sample A) was washed with boiling water. During this process, the honeydew was extracted from cotton fibers. The washed cotton was dried in oven at 150 ^{o}C for 20 minutes. The second part (i.e. sample B) was used without washing, instead it was only heated at 150^{o}C for 20 minutes. During this process, honeydew was allowed to caramelize and its color changed to yellow and brown. In addition, any contaminating honeydew converted into a non-sticky or non-adhesive and brittle form. Heating did not cause any discoloration or color change of cotton fibers. The yellow index (+b) of samples A and B were measured by colorimeter. Finally, cotton stickiness index was calculated from Equation 1. The results of this method are shown in Table 1 as “stickiness Index”.

Stickness=Yellow index of sample B -Yellow index of sample A (1)

3. Results and discussion

In this work, the cotton fibers stickiness was measured by a novel mthod based on color paramter of raw and heated cotton fiber. The peformance of new method was evaluated by comparison with sugar content test and the thermodetector methods. The results of stickiness estimation by the colorimetric method, sugar content test and the thermodetector methods are presented in Table 1. For comparing the stickiness index in colorimetric method with the results of other methods, cotton fibers was graded in three categories of bad, medium and good quality by using Minitab statistical software. The similarity level of clustering was 93.71%. Table 2 shows the statistical results of three categories as mean, maximum (max), minimum (min) and standard deviation (STD) values.

A high-quality cotton fiber has little sugar content, small yellow index or stickiness index and few sticky points number. Similar results are obtained from Figures 1 and 2. In these figures, there are good correlation between stickiness index and sugar content and sticky points number of thermodetector method. The coefficient of correlation between stickiness index and sugar content is 0.93 and the coefficient of correlation between stickiness index and sticky points number is 0.9. The obtained results show that the results of colorimetric method is more closely correlated to sugar content test than the thermodetector method.

Table 2: The relationship between sugar content test (Sugar content), thermodetector method (Sticky points number) and colorimetric method (Stickiness index).

Cotton fibers grade	Samples number		Sugar content (%)	Sticky points number	Stickiness index
Good	5	Mean	0.154	2.500	1.503
		Std	0.082	0.480	0.223
		Max	0.280	3.000	1.800
		Min	0.080	2.000	1.200
Medium	5	Mean	0.556	5.187	2.193
		Std	0.090	0.734	0.169
		Max	0.680	5.800	2.400
		Min	0.480	4.200	1.967
Bad	3	Mean	0.920	6.689	3.401
		Std	0.040	0.301	0.325
		Max	0.960	7.000	3.727
		Min	0.880	6.400	3.077

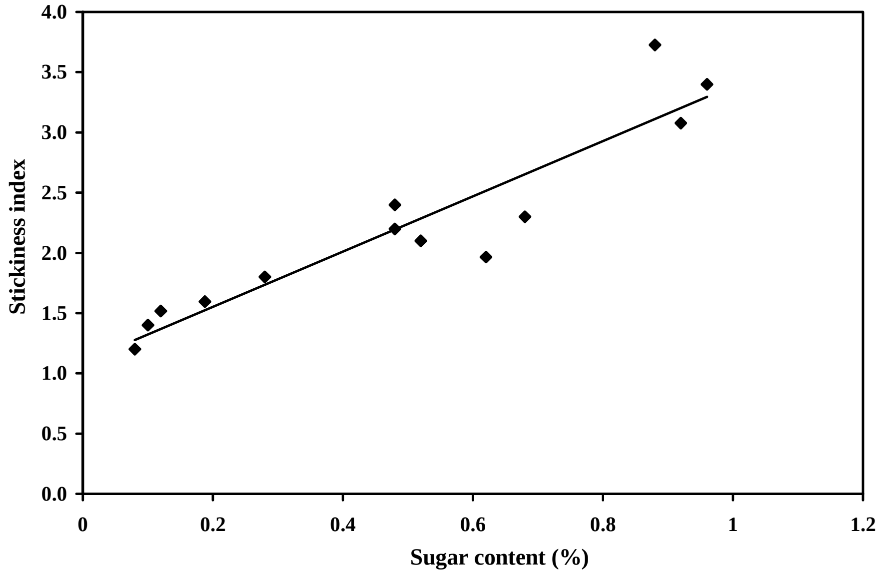

Figure 1: The relationship between Stickiness index and sugar content in cotton fibers.

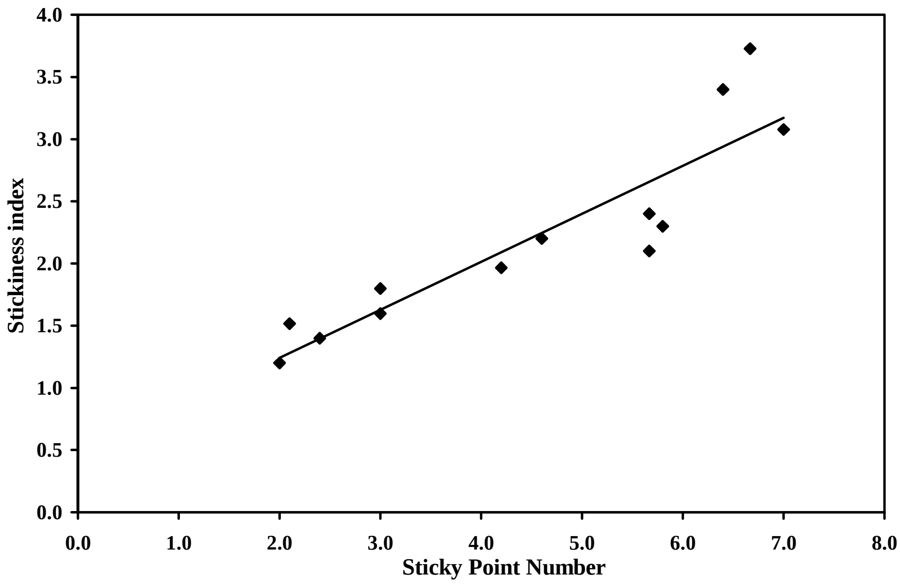

Figure 2: The relationship between Stickiness index and sticky points number.

The whitefly honeydew in cotton fiber exhibits high levels of melezitose and trehalulose saccharides. The concentration of both of melezitose and trehalulose is decreased by heating (Figures 3 and 4).

As shown in these figures the rate of degradation of trehalulose is more than melezitose[15]. In colorimetic method, the caramelization of honeydew in cotton fiber due to heating casuses color change. In this method, the color of honeydew was changed to yellow and brown. The correlation between the results of coloremetric method as Stickiness index and that of sugar content test is more than the correlation between the results of coloremetric and thermodetector methods.

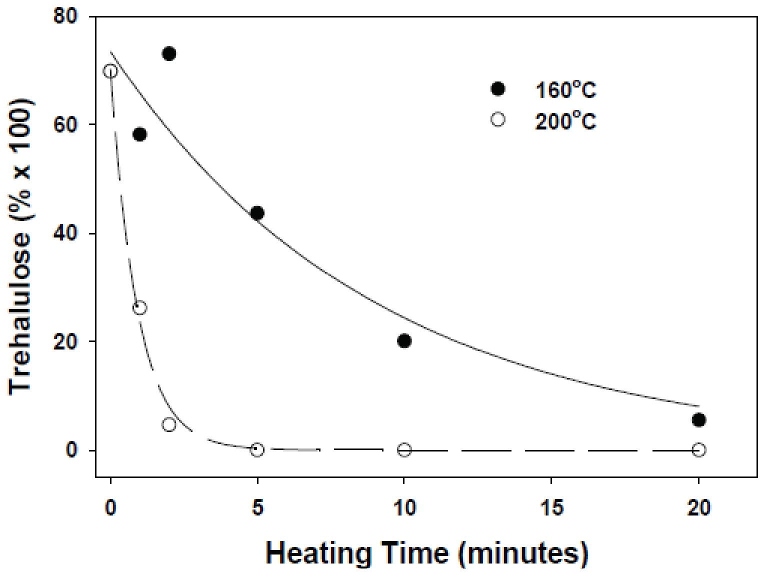

Figure 3: The effect of heating on concentration of trehalulose on cotton lint contaminated with whitefly honeydew [15].

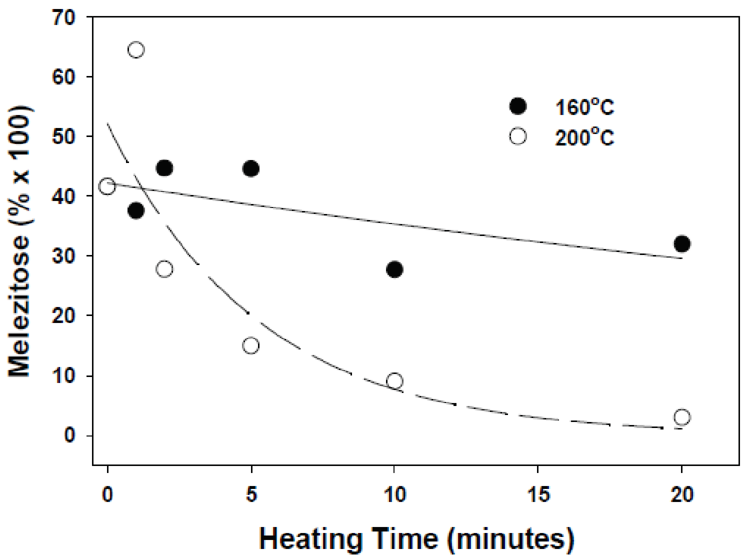

Figure 4. The effect of heating on concentration of melezitose on cotton lint contaminated with whitefly honeydew [15].

4. Conclusions

Cotton stickiness depends on sugar content of cotton fibers. The sugar content and stickiness of cotton fibers have been measured by several methods. In this work, it was tried to measure cotton fibers stickiness by colorimetric method. In this method, honeydew was allowed to caramelize by heating. During this process, the color of honeydew was changed to yellow and brown.

The yellow index of caramelized honeydew on cotton fibers was used to estimate the cotton fibers stickiness. The obtained results show that the colorimetric results are highly correlated to other methods. Also, the results of colorimetric method are more closely correlated to sugar content test than the thermodetector method. This new method is a semi-quantitative and high-speed method.

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