A NEW METHOD TO RAPIDLY ASSESS THE STICKINESS OF COTTON


ABSTRACT. Rapid assessment of the stickiness of cotton can be accomplished with a new apparatus designed, constructed, and tested at the U.S. Cotton Ginning Laboratory at Stoneville, Mississippi, and at a commercial laboratory. The apparatus essentially consists of a cabinet equipped with an infrared moisture sensor, resistance sensor, and compression platen. The apparatus may be used as a stationary laboratory device or it may be used for continuous, online monitoring in a gin or textile environment. The infrared moisture meter responds to the level of natural sugar and insect sugar that is contained within the sample whereas the resistance moisture content is affected only slightly. Results of several studies involving a number of cottons grown across the cotton belt indicated that the instrument can correctly estimate whether a sample is sticky or not about 75% of the time. Keywords. Cotton, Stickiness, Sugar, Infrared, Resistance, Mill processing.

Stickiness problems become apparent when certain contaminants present on the cotton fibers begin to interfere with the smooth operation of textile processes such as carding and spinning. These contaminants are usually sticky, sugary deposits produced either by feeding insects or by the cotton plant itself. These insect deposits are often referred to as honeydew. At the gin, reduced ginning rates and poor operation can occur as a result of sticky cotton. These effects are less pronounced at the gin than those that occur during textile processing.

Cotton stickiness can result from two causes—sugars present on the fibers and from miscellaneous factors (Hector and Hodkinson, 1989). Sugar is a colloquial term used to describe certain members of the class of compounds called carbohydrates. Sugars have hydrophilic properties. These molecules possess several hydroxyl groups which can interact with water molecules; in essence, they take up water and become sticky. The sugars present on cotton fibers can be divided into two main types reflecting their origin: (1) physiological sugars produced by the plants themselves, and (2) entomological sugars produced by feeding insects. Occasionally, microorganisms may also be responsible for sugar contamination of cotton.

The physiological or natural fiber sugars can be subdivided into those originating as (a) cellulose precursor and as (b) nectary-secretions. Entomological sugars attributable to honeydew cause 80 to 90% of all cases of cotton stickiness (Sisman and Schenck, 1984). Honeydew from whiteflies is the main cause of sticky cotton (Rimon, 1982). The main honeydew producing insects attacking U.S.-grown cotton are the sweet potato whitefly Bemisia tabaci Gennadius and the cotton aphid Aphis gossypii Glover.

Whiteflies and aphids are both plant sap-sucking insects which feed by inserting their slender mouthparts (stylets) into the leaf tissue (Anonymous, 1988). Sap is then drawn up into the insect along the stylet food canal. Phloem sap is generally rich in sugars but poor in the amino acids which are essential for insect growth. Whitefly and aphids therefore have to ingest large amounts of sap in order to obtain sufficient amino acids for growth. The insects do only a little digestion and the residual solution is stored in the dilated rectum before ejection to the exterior in the form of a droplet of honeydew. The honeydew droplet released is rich in excess sugars. The droplets are intact on seed cotton but the combing and blending action of gin cleaners spread each droplet over a larger area.

CURRENT TESTS FOR SUGARS AND STICKINESS

Stickiness was originally thought to be directly related to the reducing sugar content, i.e., the glucose and fructose content of the cotton sample, and many of the earlier tests for stickiness involved measurement of the reducing sugars. Sugar contents greater than 0.3% reducing sugars by weight usually indicate that stickiness problems might occur (Elsner et al., 1983) although in Texas a sugar content greater than 0.6% would usually be expected to be sticky during processing. Roberts et al. (1978) stated that stickiness was directly correlated with reducing sugar content and Heuer and Plaut (1985) concluded that stickiness was quantitatively related to the reducing compounds, mainly sugars, which were part of the structure of the fiber. Similarly, Bezouska (1985) indicated that reducing sugar content is often used as a measure of the stickiness of raw cotton. There are many simple

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chemical tests for reducing sugars, generally involving the
eXtraction of cotton lint with water and examining the color
reactions of the extract after the addition of certain
chemicals (Milnera, 1983).
Near infrared spectroscopy (NIR) is currently being
investigated as a rapid method for measuring reducing
sugars on cotton, but Perkins (1980) points out the major
drawback with NIR in that it only tests a relatively small
volume of cotton. This criticism, however, can be leveled
at all methods of measuring sugars and stickiness. Sugars
may be unevenly distributed within a cotton bale and their
detection depends on the adequacy of the sampling
program. Ideally, several samples should be taken and
tested.
A second, relatively longer pressure of a few minutes is
then exerted without heat after which the preparation is left
to settle. The cotton web is then removed from the
aluminum sheets but the sticky spots adhere strongly and
remain attached to the sheets. This method has certain
advantages over the Minicard, yet results seem to correlate
well with the Minicard test. The thermodetector is compact
and needs little maintenance; the test is simpler and less
expensive than the Minicard, takes about 10 to
12 min/sample using one operator, and has the advantage
that permanent records can be obtained in the form of
aluminum foil sheets with attached spots.

MATERIALS AND METHODS
Identification of the stickiness of cotton at the gin,
textile mill, or laboratory cannot be done quickly with
existing technology. The current methods of determining
the sugar content and/or stickiness of cotton involve using
laboratory methods that are not applicable to rapid or
continuous on-line-type measurements. Preliminary
research into this area indicated that the different types of
measurements of moisture content such as resistance
determinations, oven drying, capacitance determinations,
and near-infrared measurements yielded different estimates
of moisture content as a function of the amount of sugars
that were on the cotton. In cases where the natural sugar
was high, the oven moisture determined by oven drying
appeared to be elevated. In cases where the insect sugar
content was high, the near infrared moisture appeared to be
depressed. The resistance-based moisture meter developed
by Byler and Anthony (1994) appeared to be relatively
unaffected by the level of natural or insect sugar in the
cotton. Consequently, an apparatus was developed which
combined measurements of resistance, infrared, and
capacitance into one machine (Anthony et al., 1994).
Initially as a matter of convenience, the cabinet for a stand­
alone Motion Control Color/Trash Meter was modified to
accept an infrared camera and a resistance sensor (fig. 1).
Essentially, the camera was removed from the cabinet and
an infrared sensor was installed in its place. A resistance
sensor was added to the underside of the platen which is
used to compress a sample of cotton up against the glass
which usually shields the camera. When a sample of cotton
is placed under the platen and compressed, readings are
taken with the infrared and resistance sensor. The
capacitance readings were made with an adjacent
instrument. The difference between these readings is used
to estimate the stickiness of the cotton in levels from 0 to 4.
As mentioned previously, stickiness is assessed by the
Minicard into levels 0, 1, 2, and 3. For this study, cotton of
stickiness level 4 (which was well beyond the level 3 as
indicated by the Minicard test) was added.
A number of samples were evaluated initially to
ascertain that the measurements were repeatable, after that,
several larger studies were conducted. In study 1, seven
canpses of cotton with unknown growth locations, but
having different levels of stickiness, were obtained from
Henry Perkins, Research Chemist with USDA-ARS at
Stoneville, South Carolina, and combined with three
samples from the west/southwest that were obtained from
Ed Hughs, Research Leader, USDA-ARS at Las Cruces,
New Mexico. These samples were subdivided into trashy
seed cotton, precleaned seed cotton, and ginned lint. In
addition, three samples of clean, low sugar, nonsticky
cotton from the Stoneville area were added for a total of 13
samples. In study 2, 29 additional samples grown in
different locations across the Cotton Belt were obtained
from Michael Watson, Associate Director of Fiber Quality
Research with Cotton Incorporated at Raleigh,
North Carolina, and combined with the original 13
samples.
samples, to which three additional samples from the Stoneville area, including lint and seed cotton, were added. These samples contained natural sugar contents ranging from 0.3 to 1.5% and stickiness levels determined by the Minicard to be from 0 to 4. In study 3, seed cotton samples from the previous two studies were isolated into separate databases and analyzed. For study 3, only two levels of stickiness were available based on Minicard readings from lint taken from the seedcotton—0 and 4. In study 4, a new model of the apparatus was constructed and tested in the Stoneville, Mississippi, laboratory and subsequently used at a commercial laboratory at Anderson Clayton Company in Phoenix, Arizona. About 100 samples of seed cotton as well as lint ginned from the same module were obtained from gins across the southwest and west and tested with the apparatus. In the second part of study 4, samples were tested as they were processed through the Anderson Clayton testing laboratory for routine fiber tests. As compared to studies 1, 2, 3, and the first part of study 4, these samples were not preselected to represent levels of stickiness, natural sugar, and moisture.

RESULTS AND DISCUSSIONS
In study 1, comparison of the infrared and resistance readings (table 1) from these samples combined with oven moisture readings indicated that cottons were usually sticky if the resistance-based moisture exceeded the infrared-based moisture by 0.8%. Samples with high natural sugar also appeared to be called sticky. When the oven-based moisture exceeded the infrared-based moisture by 0.6%, and the resistance-based moisture exceeded the infrared-based moisture by 0.8%, it appeared that these samples had a high sugar content but were not sticky—it appeared that the sugar in this lint was due to physiological (natural plant) sugars. Thus by combining these three measurements of moisture content, samples could be separated into three categories: sticky, nonsticky, and high natural sugar. Further analysis of these data using the Discriminate Analysis procedure by the Statistical Analysis System (SAS) indicated that these 13 samples could be divided into categories of 0, 1, 2, 3, and 4 regardless of the natural sugar by using only the resistance and infrared methods. For each of the samples, two readings were taken on a side of the cotton and the sample turned over and two additional readings taken. These data were averaged to produce one data point. When this procedure was replicated on different days for a total of three times, 12 of the 13 samples were correctly identified; when oven moisture was included, 13 of the 13 samples were correctly identified. Consideration of the capacitance readings in addition to the other measurements did not increase the precision, although there was some indication that the capacitance method yielded similar measurements to the

<table>
<thead>
<tr>
<th>Sample (No.)</th>
<th>Moisture (%)</th>
<th>Reducing</th>
<th>Predicted</th>
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<tbody>
<tr>
<td></td>
<td>R†</td>
<td>IRt</td>
<td>C§</td>
</tr>
<tr>
<td>1</td>
<td>7.3 6.5 6.8 7.3</td>
<td>0 0 0</td>
<td>1††</td>
</tr>
<tr>
<td>2</td>
<td>7.5 6.6 6.8 7.0</td>
<td>0 0 0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>6.6 6.7 6.9 6.9</td>
<td>0 0 0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>7.3 6.4 6.6 6.6</td>
<td>0 0 0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>7.3 6.7 6.7 6.6</td>
<td>0 0 0</td>
<td>0</td>
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<td>13</td>
<td>7.5 6.6 6.6 6.9</td>
<td>0 0 0</td>
<td>0</td>
</tr>
</tbody>
</table>

* Resistance-based method.
† Infrared-based method.
‡ Capacitance-based method.
§ Oven-based method.
∥ Natural plant sugars.
# 0 = not sticky, 1 = slightly sticky, 2 = moderately sticky, 3 = sticky, and 4 = very sticky.
** Based on moisture measurements by infrared and resistance technique.
†† Indicates misclassification. This sample was correctly identified when moisture measurements by infrared, resistance and oven techniques were used.
‡‡ Data not available.
To slightly improve the ability to predict sample stickiness. For replication 5, each of the samples were processed through one additional stage of lint cleaning in order to smooth and comb them, and perhaps return the samples closer to their original condition. This procedure improved the accuracy of predicting the level 1 stickiness. For replication six, the procedure was further modified. Eight readings were taken on a side by moving the sample about 1 in. between each reading in order to ensure that a spot of insect sugar was considered directly. The sample was then turned over and eight readings made on the other side. This procedure appeared to increase the prediction of the level 0 sample by two percentage points. Results from six replications were combined into one database to determine if the prediction accuracy changed as a result of the different handling techniques. With the combined database, 65, 27, 80, 100%, and 100% of the samples were correctly classified as 0, 1, 2, 3, and 4 stickiness levels, respectively. Thus, it appears that repeated handling of the samples impacts the effectiveness of the device. The Minicard classification of the samples was then changed to either sticky or nonsticky without regard to level of stickiness. With this approach 78% of the nonsticky samples and 85% of the sticky samples were correctly identified.

For the eight samples of seed cotton for study 3 (four sticky and four nonsticky samples, data not shown), 100% of the samples were correctly identified by the apparatus. This increased precision was likely due to the fact the insect sugar droplets were still intact on the surface of the cotton and had not been broken up, combed, and blended as would occur during normal ginning and lint cleaning operations.

In study 4, 94 samples were submitted by ginners as being "sticky". Ginners submitted raw seed cotton samples as well as 27 lint samples ginned from the same module. The stickiness of the 27 lint samples was estimated with the thermodetector method. For the thermodetector method, the level of stickiness was classified as light, medium, and strong depending on the number of sticky fiber spots per 2.5 g of lint, i.e., 2 to 16, 17 to 32, 33 to 50, respectively.

Of the 27 lint samples tested by the thermodetector method, 8, 14, and 5 were classified as stickiness levels 1, 2, and 3, respectively, by the Anderson Clayton thermodetector method (table 3). None were classified as "not sticky". Six of those 27 samples were misclassified with the Discriminant Analysis technique of SAS based on the data from the apparatus. One sample was misclassified from 2 into 1; two from 2 into 3; one from 1 into 2; one from 3 into 2; and one from 3 into 1. In essence, 88, 71, and 40% of the samples were correctly placed into the correct categories of stickiness 1, 2, and 3. Since all of these samples were sticky, the accuracy of the Discriminant Analysis technique may have been altered because no nonsticky samples were included to facilitate discrimination.

The misclassified lint samples were also evaluated at the ARS Cotton Quality Research Station at Clemson, South Carolina, using a thermodetector as well as a Minicard. Results were as follows:

<table>
<thead>
<tr>
<th>Thermodetector Spots</th>
<th>Thermodetector Level</th>
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<tbody>
<tr>
<td>Anderson Clayton</td>
<td>ARS</td>
</tr>
<tr>
<td>70</td>
<td>53</td>
</tr>
<tr>
<td>43</td>
<td>20</td>
</tr>
<tr>
<td>32</td>
<td>15</td>
</tr>
<tr>
<td>36</td>
<td>11</td>
</tr>
<tr>
<td>19</td>
<td>9</td>
</tr>
<tr>
<td>41</td>
<td>38</td>
</tr>
</tbody>
</table>
The thermodetector measurements differed substantially on four of the six readings. Further investigation was not conducted to ascertain the basis for the differences.

Further efforts to measure the stickiness of a large number of samples representing a wide range of stickiness were hampered by the lack of samples that were sticky. Cotton production in the southwest and west in the 1993 crop year generally was not sticky.

**SUMMARY**

Cotton yield as well as cotton processibility at the gin and textile mill are severely degraded by the presence of excess insect sugar on the cotton lint. Whiteflies and aphids secrete a concentrated sugary mixture on cotton that makes it "sticky". Some cotton production areas are penalized monetarily because of their reputation for sticky cotton. Rapid measurements of the stickiness of cotton are not currently available. As a result of the need to rapidly evaluate the level of stickiness of cotton, a new apparatus was designed, constructed, and tested to rapidly assess cotton stickiness. The apparatus essentially consisted of a stand-alone Motion Control Color/Trash Meter cabinet with the color/trash meter removed and replaced with an infrared moisture sensor, and the compression platen removed and replaced with a resistance moisture sensor. The infrared moisture meter responds to the level of natural sugar and insect sugar that is contained within the sample whereas the resistance moisture content is affected only slightly. The device predicts the stickiness of cotton correctly about 75% of the time to analyze the sample. This device could be integrated into a gin or mill system to provide a mechanism to regulate additives and procedures to improve processibility. Successful development and implementation of this device could improve the market potential for cotton grown in the United States, especially the southwest.

**REFERENCES**


