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HPLC of Insect Honeydew Deposits Collected from the High Speed Stickiness Detector

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ABSTRACT

The objective of this work is to study the composition of insect honeydew deposits collected from the high speed stickiness detector (H2SD). Both the effects of the hot plate temperature and the cleaning roll pressure of the H2SD on honeydew-contaminated cottons are evaluated. The tested materials consist of samples from 27 bales contaminated by whitefly honeydew (from geographic Area 1), 27 bales contaminated by aphid and whitefly honeydew (from geographic Area 2), and 27 bales contaminated by aphid honeydew (from geographic Area 3). Analyses of the data reveal strong interactions of hot plate temperature, cleaning roll pressure, and contamination type. The HPLC analysis of sticky deposits collected from the H2SD aluminum foil shows that for cotton contaminated with whitefly honeydew, trehalulose is the dominant sugar and the main cause of stickiness. However, for cotton contaminated with aphid honeydew, unidentified compounds are suspected of being major contributors to stickiness.

The primary source of cotton stickiness is attributed to the presence of excess sugars on the surface of the lint. These sugar deposits are produced either by the cotton plant (physiological sugars) or by feeding insects (entomological sugars). The presence of sucrose ($C_{12}H_{22}O_{11}$) is a major indicator of contamination with physiological sugars [6]. The presence of trehalulose ($C_{12}H_{22}O_{11}$) and melezitose ($C_{18}H_{32}O_{16}$), with trehalulose being dominant, is an indication of contamination with whitefly honeydew, while the presence of melezitose along with a very small amount of trehalulose is an indication of contamination with aphid honeydew [6].

Cotton stickiness is a very serious problem for the textile industry because it damages yarn quality and textile mill productivity [11, 14]. Poor yarn quality is mainly due to the unevenness in the flow of fibers being drawn during processing, while low productivity is the result of decreased throughput, a more frequent cleaning schedule (necessary to clean off the residues accumulated on the textile equipment), and excessive ends-down. A number of mechanical instruments were developed to evaluate the stickiness potential of cotton fibers before processing: the Minicard instrument [1], the fiber contamination tester (Lintronics, Israel) [13], the sticky cotton thermodetector (CIRAD, France) [2], and the high speed stickiness detector (CIRAD, France) [3]. Among these technologies, the high speed stickiness detector (H2SD) has the potential to be a fast and reliable technique for stickiness measurements [7].

In previous work, we reported on the implication of trehalulose in the residue build-up on textile equipment during processing of moderately sticky cotton [8]. We concluded that a low melting point and high hygroscopicity explained why trehalulose was accumulating the most on the equipment. Therefore, since sugars involved in cotton stickiness have different thermal and hygroscopic properties, we conducted another study to investigate the effect of the H2SD hot plate temperature settings and relative humidity on H2SD measurements [9]. We showed that at the manufacturer-recommended hot plate temperature setting (53°C), all kinds of honeydew caused stickiness, while at a lower hot plate temperature, only trehalulose-rich honeydew caused stickiness. Thus, the origin of the contamination (whiteflies or aphids) has an effect on the H2SD readings. The honeydew droplets with a high percentage of trehalulose are sticky at any H2SD hot plate temperature above 25°C , while honeydew droplets with a low percentage of trehalulose are not [10].

In this paper, we report the combined effect of the H2SD hot plate temperature and the cleaning roll pressure on stickiness measurements and the kinds of sugars sticking on the H2SD's aluminum foil.

Materials and Methods

A subset of 81 honeydew contaminated cotton bales were selected from the set of 150 bales described in previous papers [8, 9]. Samples came from three different geographic growing areas. Twenty-seven bales were

contaminated mainly by whitefly honeydew (from geographic Area 1), 27 bales were contaminated by aphid and whitefly honeydew (from geographic Area 2), and 27 bales were contaminated mainly by aphid honeydew (from geographic Area 3).

Among the 81 contaminated cotton bales, we selected two to illustrate the differences in the chromatograms of whitefly honeydew-contaminated cotton versus aphid honeydew-contaminated cotton. The cotton sample selected from the geographic Area 1 was contaminated by whitefly honeydew (33.9% trehalulose and 19.1% melezitose, in percent of the HPLC total sugars). The cotton sample selected from geographic Area 3 was contaminated by aphid honeydew (0.6% trehalulose and 10.2% melezitose).

HIGH SPEED STICKINESS DETECTOR TEST AT DIFFERENT SETTINGS

The principle of the H2SD for cotton stickiness measurements is based on a thermodetection method [4, 5]: after conditioning the cotton fibers for at least 12 hours, a specimen of 3.25 ± 0.25 g is fed into the instrument to be mechanically opened. It forms a pad of 130 ± 10 mm by 170 ± 10 mm. The sample is then automatically transferred onto a strip of aluminum foil originating from a roll. The aluminum is rolled along a conveyor belt that carries the sample to the front of each station, then is rolled up at the other end of the machine.

The H2SD has four distinct stations. The first is a hot press, where pressure is applied for 25 ± 2 seconds at 53°C while in contact with the cotton. A force of 1500 ± 100 N is exerted on the heating plate, and its surface area is 192 cm^2 (tolerance $\pm 1\text{ cm}^2$). The second station is a cool press, where pressure is again applied for 25 ± 2 seconds at ambient temperature. This fixes the spots of melted sugar (sticky points) to the aluminum foil. The same amount of pressure is applied as during the hot-pressure phase. The third station is the cleaning station where the nonsticky fibers are removed by a combination of a cleaning roll and suction. The fourth station is an image analysis chamber, where the sticky points are counted by a computerized camera.

We have selected two hot plate temperatures, 53°C and 27°C , and two cleaning roll pressures, a high cleaning roll pressure (H) and a low cleaning roll pressure (L). We selected the high cleaning roll pressure (H) because at a higher cleaning pressure, the aluminum foil could be damaged and some sticky points could be removed. We selected the low cleaning roll pressure (L) because it was the lowest pressure that could still clean the foil. The pressure of the cleaning roll was set by measuring the distance between the aluminum foil and the cleaning roll (carpet excluded), as shown in Figure 1. Three samples

FIGURE 1. Schematic of the cleaning roll pressure setting.

per bale (~ 10 g) were tested on the H2SD (three replications per sample). Four different combinations of settings for the hot plate temperature and the cleaning roll pressure were used: (1) 53°C and high cleaning pressure is denoted as 53H, (2) 53°C and low cleaning pressure is denoted as 53L, (3) 27°C and high cleaning pressure is denoted as 27H, and (4) 27°C and low cleaning pressure is denoted as 27L.

HIGH PERFORMANCE LIQUID CHROMATOGRAPHY ANALYSIS

To determine the sugar composition of the sticky deposits, the sticky spots were collected after the image analysis system using wet wipes (Kim wipes EX-L, wetted with distilled water, Kimberly-Clark, GA), stored in plastic bags, and frozen. The sticky deposits coming from three H2SD replications were placed in the same bag. After completion of the stickiness tests, sugars were extracted from the wipes using 20 ml 18.2-megahom water, and the HPLC tests were conducted using the procedure described in our previous papers [8, 9]. The sugar content was calculated from the peak area of known sugars.

EVALUATING THE STICKINESS POTENTIAL OF IDENTIFIED SUGARS

Trehalulose sugar was obtained through Cornell University; the other sugars were purchased from Sigma Chemical Company (St Louis, Mo). Commercial syrups (mixes 3 and 4) were obtained from MitsuiUSA Inc. (Misui & Co., NY). These mixes contain palatinose in addition to glucose, fructose, trehalulose, and sucrose. To evaluate the stickiness potential, hydrated sugar mixes 1, 2, and 5 were prepared from inositol, glucose, fructose, trehalulose, sucrose, and melezitose (Table I).

TABLE I. Sugar mixes tested by the adhesiveness test: I = inositol, G = glucose, F = fructose, W = trehalulose, S = sucrose, M = melezitose, Pal = palatinose.

Mixes	I	G	F	W	S	M	Pal
Mix 1	5%	15%	15%	5%	15%	45%	0
Mix 2	5%	10%	10%	45%	15%	15%	0
Mix 3 ^a	0	5.2%	6%	74.2%	1.1%	0	11.9%
Mix 4 ^a	0	1.1%	1.2%	85%	0.2%	0	12.5%
Mix 5	0	0	0	99.8%	0	0	0

^aCommercial syrup.

To prepare mixes 1, 2, and 5, the dehydrated sugars were weighed and mixed with a spatula. The open containers with the mixed sugar samples were stored at $65 \pm 2\%$ relative humidity and $21 \pm 1^\circ\text{C}$ for more than one month. Because of the high hygroscopicity of trehalulose and fructose, hydrated mixes had the consistency of glue. Mixes 3 and 4 were commercial syrups, which were stored at $65 \pm 2\%$ RH and $21 \pm 1^\circ\text{C}$, then tested as is. Two pieces of cotton yarn (~ 30 cm long) were impregnated with the sugar mixes and stuck together, as shown in Figure 2 (the sugar mixes acted like glue). The adhesiveness test measures the force (peak load) needed to separate the two pieces of cotton yarn using a dynamometer, Testometric UT350 (The Testometric Company Ltd., U.K.), with ten replications from each mix.

FIGURE 2. Adhesiveness test schematic.

Results and Discussion

Table II summarizes the sugar contents of honeydew-contaminated cotton bale samples, measured by HPLC and expressed as the percent of total sugars. All bales having less than ten sticky spots with a hot plate temperature setting of 53°C and low pressure of the cleaning roll were not included in this study. As shown in previous work [12], the H2SD number of sticky deposits among readings within a cotton sample follows a Poisson-like

distribution; therefore, a square root transformation is adequate to normalize data prior to statistical analysis. Consequently, all H2SD readings reported in this work and the statistical analyses were on the square root transformed data.

EFFECT OF H2SD HOT PLATE TEMPERATURE AND CLEANING ROLL PRESSURE

The H2SD measurements for Areas 1, 2, and 3 at different H2SD settings showed an increase in the number of H2SD sticky deposits when the H2SD hot plate temperature increased from 27 to 53°C for the three areas tested. On average, for both cleaning roll pressures, the H2SD readings increased by 49.3% for Area 1, 52.5% for Area 2, and 157.0% for Area 3. However, when compared to the low cleaning roll pressure, the number of H2SD sticky deposits decreased with the high cleaning roll pressure for the three areas tested. On average, for both H2SD hot plate temperatures, the H2SD readings decreased by 42.6% for Area 1, 48.3% for Area 2, and 30.8% for Area 3. Furthermore, the analysis of variance showed significant two-way interactions of all the factors tested (Table III). Indeed, Area 3 appeared to be much more sensitive to the hot plate temperature and somewhat less sensitive to the cleaning roll pressure than Areas 1 and 2.

Hot plate temperature setting at 27°C : The relationship between the H2SD readings at low and high cleaning roll pressures with the hot plate temperature set at 27°C is linear. There are no slope differences between the three areas, so a global linear regression can be calculated. As shown in Figure 3a, the intercept is not different from 0 ($[-0.052, 0.348]$) and the slope is equal to 0.520, with a 95% confidence interval of $[0.469, 0.570]$. On average, the H2SD readings at the high cleaning roll pressure are 43.9% lower than at the low cleaning roll pressure. The decrease of the H2SD readings at high cleaning roll pressure is attributed to the fact that some sticky spots with a low adhesion to the aluminum foil are removed.

Hot plate temperature setting at 53°C : The relationship between the H2SD readings at low and high cleaning roll pressures with the hot plate temperature of 53°C is much more complex. Two groups with fundamentally different behaviors are distinguished. For Areas 1 and 2, the relationships are linear and there is no slope difference between the two areas. A global linear regression can be calculated. As shown in Figure 3b, the intercept is not different from 0 ($[-0.808, 0.079]$) and the slope is equal to 0.622, with a 95% confidence interval of $[0.553, 0.692]$. On average, the H2SD readings at high cleaning pressure are 43.7% lower than at low cleaning pressure

TABLE II. Sugar content of honeydew contaminated cotton samples, as measured by HPLC, expressed in percent total sugars: I = inositol, T = trehalose, G = glucose, F = fructose, W = trehalulose, S = sucrose, M = melezitose, MAL = maltose.

Geographic growing area		Sugar contents, % of total sugars							
		I	T	G	F	W	S	M	MAL
Area 1	average	13.7	6.3	16.9	20.6	23.7	0.3	14.2	4.2
	minimum	6.4	3.1	8.2	12.7	2.8	0.0	0.0	0.3
	maximum	21.0	14.7	33.6	35.1	41.7	1.5	36.7	10.7
Area 2	average	19.1	1.1	20.1	24.4	13.5	2.3	18.7	0.7
	minimum	7.9	0.2	12.1	8.6	0.7	0.1	7.0	0.3
	maximum	36.9	5.1	36.5	36.5	29.4	5.9	25.6	1.4
Area 3	average	17.6	5.8	25.4	28.2	0.2	8.9	11.4	2.6
	minimum	8.4	0.9	13.8	13.1	0.0	1.4	2.4	0.3
	maximum	33.3	16.3	37.3	46.5	1.7	23.8	28.3	6.9

TABLE III. Variance analysis on the square root transformed data: combined effect of cleaning roll pressure and hot plate temperature settings on H2SD readings.

	Df	F	Probability	H2SD ^a
Intercept	1	2686.07	0.000001	
area	2	2.77	0.064152	
1				4.18
2				3.85
3				3.76
Temperature	1	208.43	0.000001	
27°C				2.84 b
53°C				5.03 a
Pressure	1	171.65	0.000001	
L				4.92 a
H				2.94 b
Area × temperature	2	13.85	0.000002	
Area 1 - 27°C				3.35 c
Area 1 - 53°C				5.00 ab
Area 2 - 27°C				3.05 c
Area 2 - 53°C				4.65 b
Area 3 - 27°C				2.11 d
Area 3 - 53°C				5.42 a
Pressure × temperature	1	6.61	0.010624	
L - 27°C				3.63 b
L - 53°C				6.21 a
H - 27°C				2.04 c
H - 53°C				3.84 b
Area × pressure	2	4.14	0.016756	
Area 1 - L				5.31 b
Area 1 - H				3.05 c
Area 2 - L				5.01 a
Area 2 - H				2.68 c
Area 3 - L				4.45 b
Area 3 - H				3.08 c
Area × pressure × temperature	2	0.01	0.988620	
Area 1 - L - 27°C				4.29
Area 1 - L - 53°C				6.32
Area 1 - H - 27°C				2.41
Area 1 - H - 53°C				3.68
Area 2 - L - 27°C				4.00
Area 2 - L - 53°C				6.02
Area 2 - H - 27°C				2.09
Area 2 - H - 53°C				3.27
Area 3 - L - 27°C				2.61
Area 3 - L - 53°C				6.29
Area 3 - H - 27°C				1.60
Area 3 - H - 53°C				4.55
Error	312			

^aH2SD readings not followed by the same letter are significantly different with $\alpha = 5\%$ (Newman-Keuls test).

for Areas 1 and 2. However, the Area 3 samples reacted differently, as shown in Figure 3c. The relationship between low and high cleaning roll pressure with the hot plate temperature of 53°C is clearly not linear for Area 3 samples. The very sticky cottons from Area 3 have approximately the same number of sticky deposits on the aluminum foil for both high and low cleaning pressures at 53°C. Such behavior did not appear at 27°C for this area. It appears that for some bales coming from Area 3 (aphid contamination), there is a compound in the honeydew that renders the sticky deposits very adherent to the aluminum foil at a high temperature of the hot plate. This compound has a high adhesion to the aluminum foil at 53°C but not at 27°C.

EVALUATING THE STICKINESS POTENTIAL OF SUGARS

Among the sugars identified in the honeydew-contaminated lint, trehalulose and fructose are the only sugars with high hygroscopicity [8]. In addition, trehalulose has a very low melting point. Therefore, it is reasonable to assume that trehalulose or fructose or both have a high adhesiveness and tend to stick to the H2SD aluminum foil. The adhesiveness tests revealed that the average peak load for hydrated fructose was 2.4 gf, while it was 11.6 times higher for hydrated trehalulose (27.9 gf). Therefore, we decided to test several sugar mixes with different trehalulose concentrations, as shown in Table I. We obtained a linear relationship between peak load and trehalulose concentration (peak load = $0.216 \text{ trehalulose}(\%) + 5.273$, adjusted $R^2 = 0.978$, $F(1,3) = 181.71$, $p < 0.001$, std. error of estimate = 1.206). The high correlation coefficient suggests that for the mixes evaluated, trehalulose alone determined the adhesiveness. The other sugars appeared to have no impact on the adhesion force. Consequently, we could expect a relationship between trehalulose content in the contaminated fibers and H2SD readings. To validate this assumption, we tested 150 bale samples with different amounts of trehalulose [9]. The global relationship between the H2SD readings and

FIGURE 3. (a) H2SD readings at 27°C and low pressure versus H2SD readings at 27°C and high pressure $H2SD_{27H} = 0.520(H2SD_{27L}) + 0.148$, adjusted $R^2 = 0.839$, $F(1,79) = 418.8$, $p < 0.001$, std. error of estimate = 0.358. (b) Areas 1 and 2: H2SD readings at 53°C and low pressure versus H2SD readings at 53°C and high pressure. $H2SD_{53H} = 0.622(H2SD_{53L}) - 0.365$, adjusted $R^2 = 0.859$, $F(1,52) = 324.78$, $p < 0.001$, std. error of estimate = 0.425. (c) Area 3: H2SD readings at 53°C and low pressure versus H2SD readings at 53°C and high pressure. $H2SD_{53H} = 0.269(H2SD_{53L})^2 - 2.106(H2SD_{53L}) + 6.597$, adjusted $R^2 = 0.811$, $F(2,24) = 56.73$, $p < 0.001$, std. error of estimate = 0.850.

trehalulose content on the lint was: $\text{trehalulose}(\%) = 0.0187 \sqrt{H2SD} - 0.0314$, adjusted $R^2 = 0.286$, $F(1,148) = 60.63$, $p < 0.001$, std. error of estimate = 0.068. This lack of correlation was also true for all sugars identified on the lint (inositol, trehalose, fructose, glucose, sucrose, melezitose, and maltose). This leads to another hypothesis that some other unidentified compound may exist on the lint to cause stickiness. This hypothesis is supported by the results reported in Figure 3c. Area 3 samples contained a compound or compounds with very high adhesion behavior. These compounds, once they were fixed on the aluminum foil, could not be removed even at high cleaning pressure. They could not be trehalulose, as the HPLC analysis clearly revealed its extremely low level for the cotton samples in Area 3 [9]. Therefore, if Area 3 is excluded from the analysis, a good non linear correlation between the trehalulose content (for samples from Areas 1 and 2) and H2SD readings is obtained, as shown in Figure 4. The nonlinear nature of this relationship is attributed to very high levels of contamination, where H2SD sticky spots have the tendency to merge and lead to a saturation phenomenon of the image analysis system.

FIGURE 4. Areas 1 and 2: trehalulose content (% of the fiber weight) versus H2SD at 53°C and low cleaning roll pressure. $H2SD = 1.819 + 42.263\text{trehalulose}(\%) - 68.196[\text{trehalulose}(\%)]^2$, adjusted $R^2 = 0.874$, $F(2,97) = 343.68$, $p < 0.001$, std. error of estimate = 0.822.

To explain the data from the Area 3 samples, we hypothesized that the unknown compound causing stickiness for the samples of this area is not one of the sugars currently identified with the HPLC. It could also be an unknown sugar present in the HPLC chromatogram, but not yet identified because of the lack of the corresponding standard. Therefore, HPLC analysis of the deposits on the H2SD's aluminum foil could help elucidate the difference between samples from Areas 1, 2, and 3.

FIGURE 3. (a) H2SD readings at 27°C and low pressure versus H2SD readings at 27°C and high pressure. $H2SD_{27H} = 0.520(H2SD_{27L}) + 0.148$, adjusted $R^2 = 0.839$, $F(1,79) = 418.8$, $p < 0.001$, std. error of estimate = 0.358. (b) Areas 1 and 2: H2SD readings at 53°C and low pressure versus H2SD readings at 53°C and high pressure. $H2SD_{53H} = 0.622(H2SD_{53L}) - 0.365$, adjusted $R^2 = 0.859$, $F(1,52) = 324.78$, $p < 0.001$, std. error of estimate = 0.425. (c) Area 3: H2SD readings at 53°C and low pressure versus H2SD readings at 53°C and high pressure. $H2SD_{53H} = 0.269(H2SD_{53L})^2 - 2.106(H2SD_{53L}) + 6.597$, adjusted $R^2 = 0.811$, $F(2,24) = 56.73$, $p < 0.001$, std. error of estimate = 0.850.

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HPLC ANALYSES OF INSECT HONEYDEW DEPOSITS COLLECTED FROM H2SD

Figure 5 shows scanning electron micrographs of sticky deposits on the H2SD's aluminum foil. These micrographs show fibers and crystals assumed to be sugars embedded in an amorphous substance (top micrographs), droplets thought to be honeydew on a fiber (bottom left), and a crystal trapped in an entangled fiber (bottom right). We used wet wipes to remove these sticky deposits from the aluminum foil after they were analyzed by the H2SD system. Sugars from the wet wipes were then extracted and analyzed by HPLC. As a control, HPLC analyses were performed on clean aluminum foil wiped with wet Kim wipes. With the exception of a small inositol peak, the HPLC profiles of the control did not show any significant peaks. Thus, all peaks shown in the chromatograms of the extracts are not due to an external source of contamination, *i.e.*, wipes or aluminum.

FIGURE 5. Scanning electron microscopy of a sticky deposit collected from the H2SD aluminum foil (whitefly contaminated cotton).

Among the sugars detected for Areas 1 and 2, trehalulose was the only one showing significant correlations between the quantities found on the lint and the quantities found on the H2SD aluminum foil (Figure 6—a log transformation was applied to the graph data in order to

better visualize the relationship). These results confirmed our previous hypothesis that at any temperature, when the lint is contaminated essentially with whitefly honeydew (Areas 1 and 2), trehalulose preferentially sticks to the aluminum foil and that explains the H2SD readings [9]. Since the trehalulose content on the lint for Area 3 is very small, such a relationship does not exist for this area. Furthermore, the other sugars identified on the lint from Area 3 do not explain the H2SD readings either (data not shown). This leads us to hypothesize that for this area, there is another compound or compounds on the lint not yet identified. These compounds could contribute to the interaction of area $\times$ temperature as noted earlier (Table III).

All chromatograms of 81 cotton samples were analyzed. To illustrate the difference in the chromatograms of samples from geographical areas contaminated with whitefly honeydew (Area 1) and aphid honeydew (Area 3), two representative cottons were selected. Figures 7a through 7c show the chromatograms for the lint and the corresponding deposits collected from the H2SD aluminum foil. These chromatograms were obtained by subtracting the chromatograms of clean aluminum wipes from those of honeydew-contaminated aluminum wipes. The results from two H2SD settings are presented: 53°C and 27°C. For both settings, the cleaning roll pressure was set to low. The analysis of these six chromatograms revealed the presence of seven individual peaks or groups of peaks that are not currently identified:

Group 1 contains a single peak that is extremely small for the two lint samples. This peak appeared on all aluminum foil deposit extracts at both temperatures tested and is much larger than on the lint. It means that this substance probably has a very low melting point but, as this compound is present at all temperatures, it could not cause the interaction of area $\times$ temperature.

Group 2 contains three individual peaks that are present on the two cotton lint samples but in different proportions. These peaks are also present on the extracts from the aluminum foil at 53°C, but they disappear at 27°C except for the lint from Area 1. It means that these peaks could, at least partly, contribute to the interaction of area $\times$ temperature.

Group 3 contains a single peak that is extremely small for the two lint samples. This peak appears on all aluminum foil deposit extracts at both temperatures and is much larger than on the lint. It means that this substance probably has a very low melting point but, as it is present at both temperatures, it could not contribute to the interaction of area $\times$ temperature.

Group 4 is one single peak that is quite small for the two lint samples. This peak is also present on the aluminum foil at 53°C, but disappears at 27°C except for the

FIGURE 6. Trehalulose on the lint versus trehalulose on aluminum foil at different H2SD settings.

lint from Area 1. It suggests that this substance could contribute to the interaction of area $\times$ temperature.

Group 5 is one single peak that is present on lint samples from Areas 1 and 3. It also appears on the aluminum foil deposits at 53°C but not at 27°C for samples from Area 3. It suggests that this substance could contribute to the interaction of area $\times$ temperature.

Group 6 consists of two peaks present on the two lint samples. It is also present on the aluminum foil at both temperatures for samples from Area 1, but disappears at 27°C for the samples from Area 3. It means that this substance could contribute to the interaction of area $\times$ temperature.

Group 7 consists of a large number of peaks that are not well separated; they appear on the two lint samples but more on the lint sample from Area 3. The intensity of these peaks at 53°C is very high compared to 27°C for

Area 3. It means that this or these substances could contribute to the interaction of area $\times$ temperature.

In summary, groups 2, 5, 6, and 7 could contribute to the interaction of area $\times$ temperature. Group 7 may be specific to aphid contamination, leading to discrimination between whitefly and aphid contaminations. These compounds may have low melting points, as they are found on the H2SD aluminum foil with the hot plate temperature setting of 53°C but not at 27°C.

Conclusions

Our results demonstrate the significant effect of the H2SD hot plate temperature and the cleaning roll pressure on stickiness measurements. On average for both cleaning roll pressures, the H2SD readings increase by 49.3%

FIGURE 7. (a) Comparison of HPLC profiles of cotton fibers from areas 1 and 3 (I = inositol, T = trehalose, G = glucose, F = fructose, W = trehalulose, S = sucrose, M = melezitose, peaks 1–7 are not identified). (b) Comparison of HPLC profiles of sticky deposits on H2SD aluminum foil of cotton fibers from Area 1. (c) Comparison of HPLC profiles of sticky deposits on H2SD aluminum foil of cotton fibers from Area 3.

for Area 1, 52.5% for Area 2, and 157% for Area 3. However, when compared to the low cleaning roll pressure, the number of H2SD sticky deposits decreases with the high cleaning roll pressure for the three areas tested. On average for both H2SD hot plate temperatures, the H2SD readings decrease by 42.6% for Area 1, 48.3% for Area 2, and 30.8% for Area 3.

The HPLC analysis of sticky deposits on the H2SD aluminum foil show that for cotton contaminated with whitefly honeydew, trehalulose is the dominant sugar in the deposits on the aluminum foil. However, for cottons contaminated with aphid honeydew, other unidentified compounds stick to the aluminum foil at the high temperature of 53°C but not at the low temperature of 27°C.

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