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Sharing current research information and trends in the fiber and textile industries.

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ITC NOW HIRING CHEMICAL MANAGER

Due to the recent retirement of Gustavo Abdalah (see next article), the ITC is searching for a full-time Chemical Processing Manager. The applicant must have a B.S. degree in chemistry, chemical engineering or closely related field, ability to work collaboratively and be able to operate computerized machinery, instruments, and equipment. Interested applicants may visit the Texas Tech University personnel website at: www.personnel.ttu.edu for more information.

ITC HONORS RETIRING LAB MANAGER

ITC personnel, family and friends honored Chemical Processing Lab manager Gustavo Abdalah with a retirement party on May 31, 2002. Gus came to the ITC from Nicaragua in 1981 and served the ITC for 21 years. Gus and his wife plan to stay in Lubbock, Texas, but will travel often to visit their children and grandchildren.

COTTON FIBER DEVELOPMENT/PROCESSING BOOK NOW AVAILABLE THROUGH ITC

A new book titled "Cotton Fiber Development and Processing" is now available. This joint project of Cotton Incorporated and the International Textile Center features an illustrated overview of the cotton industry compiled by distinguished scientists, engineers and cotton experts. The 88-page, 8 x 8.5 inch quality paperback book contains easy to understand explanations and pictures making it interesting to the casual reader yet useful for teaching and scientific reference. More than 18 topics explain the major phases of cotton development and processing: seed germination, emergence, boll development, harvesting, ginning, fiber evaluation and yarn and fabric formation. "Cotton Fiber Development and Processing" is only $15 plus shipping and handling. Please see the ordering form on the back page of this newsletter, or visit our website: www.itc.ttu.edu for more information.

ITC TRAVEL

- 91st Convention of Texas Cotton Association, Galveston, TX, April 17-19, Dean Ethridge attending
- Texas Sheep & Goat Raiser's Association Meeting, San Angelo, TX, May 9, Dean Ethridge attending
- SBCCOM Project Annual Conference, Tampa, FL, April 17-20, S. Ramkumar attending
- TRI Environmental Incorporated, Austin, TX May 8-12, S. Ramkumar attending
- PIMA Summit Production Conference, Fresno, CA, May 13-14, Eric Hequet presentation
- Cotton Incorporated, Cary, NC, May 28-30, Eric Hequet, Noureddine Abidi, Pauline Williams to discuss current projects between CI and ITC
- 15th Annual Cotton Incorporated Engineered Fiber Selection Conference, Memphis, TN, June 10-13, Dean Ethridge attending, Eric Hequet presentation
- Southwest Drycleaning Association Research & Technology Meeting, Dallas, TX, June 21-22, Noureddine Abidi presentation

PROCESSING STICKY COTTON: IMPLICATIONS OF TREHALULOSE IN RESIDUE BUILD-UP

Eric Hequet
Noureddine Abidi

Cotton Incorporated and the Texas Food and Fibers Commission funded the research reported here.

Cotton stickiness caused by excess sugars on the lint, from the plant itself or from insects, is a very serious problem for cotton growers, cotton ginners and yarn spinners (Hequet et al., 2000 ; Watson, 2000). During the transformation process from fiber to yarn—opening, carding, drawing, roving and spinning—sticky cottons contaminate the machinery. The degree of contamination varies depending on the processes involved and the locations within the machines. This affects detrimentally both processing efficiency and quality of the textile products.

Stickiness is primarily due to sugar deposits produced either by the cotton plant itself (i.e., physiological sugars), or feeding insects (i.e., entomological sugars) (Hendrix et al., 1995). Insects have been documented as the most common source of contamination in some studies (Sisman et al., 1984). The analysis of honeydew from *Aphis gossypii* Glover and *Bemisia Argentifolii* Bellows and Perring [= *B. tabaci* (Gennadius) strain B] has shown that the aphid honeydew contains around 38.3% of melezitose plus 1.1% of trehalulose, while the whitefly honeydew contains 43.8% of trehalulose plus 16.8% of melezitose under the conditions described by Hendrix et al., 1992. Other relative percentages may occur depending on the environmental or feeding conditions. Furthermore, Miller et al. (1994) demonstrated that stickiness is related to the type of sugars present on the lint. The authors showed that trehalulose and sucrose, both disaccharides, were the stickiest sugars when added to clean cotton while melezitose (trisaccharide), glucose and fructose (both monosaccharide) were relatively non-sticky.

Gutknecht et al., 1986 reported that stickiness caused by honeydew depends on the relative humidity, which is function of both water content and temperature of the air, in which the contaminated cotton is processed. Frydrych et al. (1993) reported that stickiness measured with the thermodetector is dependent on the relative humidity. Price (1988) noticed that sticky cotton (with 1.2% reducing sugar content) stored in high relative humidity (70°F, 80%RH) gave more problems during processing than the same sticky cotton stored at low relative humidity (75°F, 55%RH). However, at low relative humidity the fibers are more rigid and will increase the friction forces creating static electricity (Morton and Hearle, 1993). Therefore, it will require more energy to draw the lint.

Stickiness is known to cause a build-up of residues on the textile machinery, which may result in irregularities or excessive yarn breakage (Hector et al., 1989). Prevention of production and quality problems requires an accelerated cleaning schedule. This study was focused on determining the origins of the residues collected on the textile equipment after processing of sticky cotton blends with low-to-moderate levels of contamination.

PROCEDURE

Twelve commercial bales contaminated with insect honeydew were selected based on their insect sugar (trehalulose and melezitose) content and their stickiness as measured with the High Speed Stickiness Detector. In addition, 5 non-sticky bales from one module were purchased for mixing with the contaminated cotton, so that alternative stickiness levels in the mixes could be obtained.

The 12 contaminated bales were broken and layered. Ten samples per bale were taken. The samples were tested as follows:

- Zellweger Uster High Volume Instrument Model 900 Automatic. Four replications were performed for micronaire and color and 10 replications for length and strength.
- HPLC (high performance liquid chromatography). Three replications were performed (10 samples per bale x 3 replications = 30 tests per bale). The results on sugar amounts are expressed as a % of the fiber weight.
- H2SD (High Speed Stickiness Detector). Three replications were performed (10 samples per bale x 3 replications = 30 tests per bale).

SPINNING TRIALS

Stickiness may cause a build-up of residues on the textile machinery, which may result in irregularities or excessive yarn breakage. When the cotton is very sticky it cannot be processed through the card; however yarn can generally be produced with low-to-moderate levels of stickiness. The common industrial practice is to blend the sticky cottons with other, non-sticky cottons, in order to produce yarns without noticeable effects in the short term. Over time, however, there will be a gradual build-up of the sugar residues on the textile machinery and equipment. This causes decreasing in productivity and quality, forcing the spinner to increase cleaning and maintenance schedules.

Seventeen mixes of sticky and non-sticky cotton were made that had low-to-moderate levels of stickiness. Behavior of these was evaluated in both ring and rotor spinning. The mechanical processes of opening, carding, drawing, roving, and spinning were done on typical industrial equipment. HPLC tests were done on card slivers, flat wastes, draw frame residues, and on the sticky deposits collected at the end of each test on the rotor spinning and ring spinning frames. These tests identify and quantify the amount of sugars, expressed as a percentage of total sugars present. Five major sugars were identified: fructose, glucose, and sucrose were the three plant sugars, while trehalulose and melezitose were the two insect sugars.

In the ring spinning trial, the yarns were spun to a 19.68 Tex (30Ne) count. Fourteen spindles were used for each mix spun, and each mix was run for 72 hours. For the open-end spinning trials, the yarn produced was 26.84 Tex (22Ne), 10 positions were used, and each mix was run for 20 hours. After each spinning test was completed, the opening line and the card were purged by processing a non-contaminated cotton, then all the equipment was washed with wet fabrics and thoroughly dried.

Analysis of sugar content in spinning dust was done using the Elitex BD200M rotor spinning machine, because it has no auto-cleaning devices to remove the dust from the rotor grooves. The dust accumulations were collected from 20 rotors after a four-hour run. The dust samples were frozen until the sugars were extracted using 20 ml of 18.2 megohm water. HPLC tests were done on the extractions and results for each sugar were expressed as a percentage of total sugars identified.

WATER ADSORPTION

The speed and amount of water adsorption by sugars will affect how readily they will convert from the crystalline state to the amorphous state. The five sugars under investigation were first dehydrated at room temperature under vacuum for 48 hours. Then they were immediately weighed in tightly closed weighing containers in controlled atmosphere, 65± 2% relative humidity and 21±1°C. The recorded weight was referred as to m_0 (dry weight) at time $t_0 = 0$ and was used for weight gain calculation. Since the stickiness tests were done at 65± 2% relative humidity and 21±1°C, the open containers containing sugar samples were stored at these conditions and weighed (weight m_t) over time until the weight stabilized (approximately four weeks). The percentage of adsorbed water on each sugar was then calculated as $[(m_t-m_0)/ m_0]*100$ and plotted against time.

DIFFERENTIAL SCANNING CALORIMETRY

During the fibers-to-yarn transformation the flow of lint is submitted to different friction forces; consequently, the temperature of some mechanical elements may increase significantly. This would be expected to affect the thermal properties of the sugars present on the contaminated lint. Once a sugar becomes sticky, the other sugars present on the lint, as well as other substances such as dusts, silica, etc., will stick on it. This could lead to unevenness in the flow of lint being drawn, resulting in lapping up on the rolls, nep-like structures, and ends-down. Therefore, the thermal properties of the 5 sugars identified on the contaminated fiber and on the residues collected on the textile equipment were investigated

The Differential Scanning Calorimetry (DSC) technique is based on the measurement of the heat flux between the sample and a reference while the temperature is rising. The sample and the reference are deposited in two different pans and heated at the same rate. In this work, the reference was an empty pan. The analysis of the DSC profiles indicates the thermal properties of the substances being tested; specific values such as melting point and decomposition point are obtained. The DSC profiles were recorded by heating at the rate of 5°C/min between 25°C and 250°C.

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RESULTS AND DISCUSSION

This paper will report only the results of the study on the composition of the residues found on the textile equipment after processing of sticky cotton blends. Results on processing performance and yarn quality will be presented in a future paper.

Sucrose is virtually the only sugar in the phloem sap of cotton plant (Hendrix et al., 1992). Sucking insects like the white fly and aphid produce trehalulose and melezitose by isomerization and polymerization of sucrose (Hendrix, 1999). Neither of these complex insect sugars occurs naturally in cotton plants; therefore, their presence on cotton lint demonstrates honeydew contamination.

The data in **Table 1** reveals that the fiber properties of the 12 contaminated bales and of the non-sticky control bales are fairly typical of Upland cottons. **Table 2** reveals trehalulose contents ranging from 0.003% to 0.188% and melezitose contents ranging from 0.025% to 0.227%. Therefore, the 12 contaminated bales all contain insect honeydew to some degree. This is confirmed by the H2SD readings ranging from 1.9 to 69.9 sticky points (**Table 2**).

Table 3 summarizes the HPLC and H2SD measurements obtained on the card slivers made from the 17 mixes of cotton. (Testing was done on the card slivers because they provide an intimate blend of the cotton fibers.) The results confirm that the mixes exhibited slight-to-moderate stickiness. During the processing of the 17 mixes, sticky deposits were noticed on the textile equipment as shown in **Figures 1** to **3**.

Figure 4-a shows average HPLC results obtained on the 17 mixes for the fiber, the flat waste, and the residues collected on the draw frame and the drawing zone of the ring spinning frame. **Figure 4-b** shows the HPLC results on residues collected on rotor spinning. In both charts the results are normalized by using the HPLC results on the fiber as the base. These charts clearly show that trehalulose content is always higher in the residues collected than on the original fibers. Therefore, the trehalulose stands out as the source of machine contamination.

The percent of each individual sugar (IS%) is calculated as follows:

IS%=
[IS/S (Fructose + Glucose +Melezitose + Sucrose + Trehalulose)] x 100

Table 4 shows the coefficients of correlation between the logarithms of IS% on the fibers, the flat strips, and the residues collected. The logarithm transformation was chosen because of the clear non-linear relationship between the variables. Results show that the correlations between fiber and flat strips are positive significant for all sugars except sucrose; therefore, the sugars in the flat strips increase when the sugars on the fibers increase. For the residues collected, however, only glucose and trehalulose are significantly correlated with amounts in the fibers. Nevertheless, the percentages of glucose in the residues are equal or lower than the percentages of glucose on the fibers (**Figure 4-a**), while there is a marked increase in trehalulose content on the residues when compared to fibers (**Figure 4-b**).

Figure 5 shows the non-linear relationships between trehalulose on the fibers from 17 mixes and trehalulose content on the residues collected from some selected locations on the textile equipment. In these figures, the trehalulose contents are expressed as precent of total sugars and the straight lines represent equality lines. The conclusion is that with mixes having trehalulose contents above 5% of the total sugars, the percentages of trehalulose content tend to increase in the residues collected.

A possible reason for the accumulation of trehalulose is a low melting point. The temperature of the textile equipment increases during processing. Therefore, the temperatures on card, drawing, roving, ring spinning, and rotor spinning frames were recorded after machine warming in a controlled environment (**Table 5**). The temperature readings were all above 25°C. The highest temperature range was recorded on the drawing frame (from 38°C to 53°C) and the rotor spinning machine (from 31°C to 38°C). The lowest temperature was recorded on ring spinning machine (from 25°C to 28°C).

DSC was chosen to study the thermal properties of the five sugars being investigated. The DSC profiles were recorded between 25°C and 250°C with a heat rate of 5°C/min. **Figure 6** shows the DSC profiles. Each sugar has two characteristic peaks corresponding to melting points and decomposition (or carbonization) points (**Table 6**). The melting points obtained are similar to those given in the Merck Index (1989), except for trehalulose, which is completely absent from the literature. Among the selected sugars, trehalulose has the lowest melting point (48°C). It begins to melt immediately when the temperature starts rising. The other sugars remain stable when the temperature rises until it reaches 116°C (melting point of fructose). Therefore, any increase in the temperature of the textile processing equipment will first affect trehalulose, causing it to either stick on the mechanical parts or become the precursor of nep formation.

The build-up of residues on the textile equipment may have long-term effects; first sticking to surfaces, then catching dust, silica, etc. This could increase the friction forces within the machinery and lead to excessive wear and temperature increases.

Another likely reason for the accumulation of trehalulose is its hygroscopic properties. Sugars belong to the carbohydrate class. They are hydrophilic because of several hydroxyl groups (-OH), which interact with water molecules, allowing many hydrogen bonds to be established. Therefore, several authors (Gutknecht et al., 1986; Price, 1988; Frydrych et al. 1993) investigated the relationship between stickiness and relative humidity. It was generally reported that contaminated cottons are less sticky at low relative humidity than at high relative humidity. The stickiness tests (Thermodetector or H2SD) should be performed in a standard textile laboratory atmosphere, according to American Society for Testing and Materials standard procedure D 1776. Thus, the quantity of water adsorbed on each sugar was evaluated at 65±2% relative humidity and 21±1°C.

The weight gain of the five sugars caused by adsorbing water from the air in a standard textile laboratory atmosphere was monitored for over two months. **Figure 7-a** shows the weight gain in percent during the first 12.6 hours of hydration. No sugar shows any significant variation within this time period except trehalulose, which picks up about 12% of moisture corresponding to 2 molecules of water per molecule of trehalulose. Trehalulose continued to pick up moisture, while fructose began to pick up moisture after 12 hours of exposure to the laboratory conditions (**Figure 7-b**). The hydration kinetic was very fast for trehalulose, with the equilibrium being reached after 80 hours, but slow for fructose, with the plateau being reached after 500 hours. The total amount of weight gain corresponds to 3 molecules of water per molecule of trehalulose and 3 molecules of water per molecule of fructose. If we assume that trehalulose accumulates more on the spinning equipment than other sugars because of its hygroscopicity, then fructose should accumulate in a similar way, but this is not the case. Indeed, the high performance liquid chromatography tests performed on the residues collected on the textile equipment do not show any increase in fructose content, even if fructose content was high on some mixes. On the 17 mixes tested, the fructose content, expressed as a percent of the fiber weight ranges from 0.012% to 0.101%; which corresponds to 10.6% to 33.6% when expressed in percent of the total sugars identified. Thus, the fact that trehalulose is highly hygroscopic does not explain alone why this sugar has the tendency to accumulate more on the textile equipment than other sugars.

CONCLUSION

Stickiness caused by honeydew contamination has been reported to cause residues build-up on the textile machinery, which may cause subsequent irregularities or yarn breakage. Seventeen mixes having a moderate level of stickiness were evaluated. In both ring and rotor spinning, trehalulose content has the tendency to increase in the residues collected on the equipment while the other sugars have not.

The study of the thermal and hygroscopic properties of the identified sugars present on contaminated lint revealed that trehalulose has the lowest melting point and a rapid rate of hydration. The combination of these properties could explain the higher concentration of trehalulose in the residues collected on the textile equipment than on the original fiber.

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Table 1: High-volume instrument results on 12 contaminated bales and 1 non-contaminated module.

Bale ID	UHML†	UI‡	Strength	Micronaire	Reflectance	Yellowness
	inch	%	g tex^{-1}		----------%----------	----------%----------
4	1.15	84.3	30.5	4.88	77.5	10.2
7	1.05	82.0	27.4	4.39	72.4	8.7
5	1.06	81.9	24.8	5.35	72.6	9.7
8	1.08	80.6	25.6	5.49	70.1	8.3
3	1.16	82.7	30.3	4.63	76.9	10.5
2	1.13	82.9	30.8	4.51	75.5	10.7
11	1.11	81.3	30.2	4.44	77.1	10.0
6	1.14	82.8	32.5	4.18	77.1	10.4
12	1.07	79.9	25.1	5.30	70.8	8.6
13	1.06	80.0	25.4	5.39	69.1	8.5
10	1.14	83.1	30.0	4.55	77.1	10.5
9	1.12	83.6	30.7	4.61	76.9	10.7
Average	1.11	82.1	28.6	4.81	74.4	9.7
Minimum	1.05	79.9	24.8	4.18	69.1	8.3
Maximum	1.16	84.3	32.5	5.49	77.5	10.7
Non-sticky module	1.09	81.7	28.7	4.88	75.9	10.6

† Upper-half mean length.
‡ Uniformity index.

Table 2: HPLC and H2SD results on 12 contaminated bales and 1nNon-contaminated module. HPLC results are expressed as a percentage of the fiber weight.

Bale ID	Glucose	Fructose	Trehalulose	Sucrose	Melezitose	Total sugars	H2SD†
	----------	----------	----------	%-	----------	----------	
4	0.048	0.017	0.003	0.010	0.033	0.112	2.3
7	0.059	0.044	0.004	0.001	0.025	0.133	14.5
5	0.030	0.031	0.049	0.001	0.052	0.163	12.6
8	0.033	0.027	0.070	0.000	0.046	0.176	22.4
3	0.110	0.075	0.004	0.010	0.032	0.231	1.9
2	0.106	0.077	0.004	0.016	0.030	0.234	2.0
11	0.118	0.081	0.018	0.019	0.040	0.276	41.5
6	0.099	0.141	0.060	0.009	0.076	0.386	18.9
12	0.073	0.122	0.186	0.001	0.155	0.536	64.7
13	0.095	0.126	0.188	0.000	0.131	0.541	69.9
10	0.130	0.197	0.129	0.057	0.191	0.705	42.8
9	0.152	0.214	0.143	0.057	0.227	0.792	38.2
Average	0.088	0.096	0.072	0.015	0.086	0.357	27.6
Minimum	0.030	0.017	0.003	0.000	0.025	0.112	1.9
Maximum	0.152	0.214	0.188	0.057	0.227	0.792	69.9
Non-sticky module	0.096	0.051	0.007	0.023	0.039	0.216	2.5

† High-speed stickiness detector.

Table 3: HPLC and H2SD on the card slivers of 17 cotton mixes. HPLC results are expressed as a percentage of the fiber weight.

Bale	Non-sticky module	Glucose	Fructose	Trehalulose	Sucrose	Melezitose	Total sugars	H2SD†
	----------	----------	----------	----------	%-	----------	----------	
1	0	0.088	0.045	0.007	0.030	0.037	0.207	3.2
2	0	0.110	0.082	0.006	0.014	0.032	0.245	2.0
3	0	0.108	0.074	0.004	0.011	0.023	0.220	2.3
4	0	0.046	0.012	0.002	0.006	0.046	0.113	3.2
5	50	0.050	0.035	0.024	0.016	0.043	0.168	8.3
5	75	0.070	0.041	0.019	0.023	0.040	0.193	6.5
6	50	0.092	0.101	0.033	0.022	0.059	0.307	8.9
6	75	0.088	0.071	0.010	0.026	0.048	0.244	4.5
7	50	0.068	0.045	0.002	0.009	0.035	0.160	10.2
7	75	0.078	0.046	0.004	0.021	0.039	0.188	4.8
8	50	0.056	0.036	0.034	0.014	0.062	0.202	15.1
8	75	0.072	0.042	0.021	0.023	0.054	0.212	6.0
9	87.5	0.094	0.075	0.031	0.044	0.071	0.315	4.7
10	87.5	0.091	0.064	0.020	0.038	0.052	0.266	5.3
11	87.5	0.086	0.048	0.005	0.027	0.036	0.202	15.7
12	93.75	0.090	0.054	0.025	0.031	0.056	0.257	9.3
13	93.75	0.094	0.055	0.016	0.026	0.043	0.233	9
	Average	0.081	0.054	0.016	0.022	0.046	0.219	7.0
	Minimum	0.046	0.012	0.002	0.006	0.023	0.113	2.0
	Maximum	0.110	0.101	0.034	0.044	0.071	0.315	15.7

† High-speed stickiness detector.

Fig. 1: **Sticky deposits on the draw frame creel drive rolls**

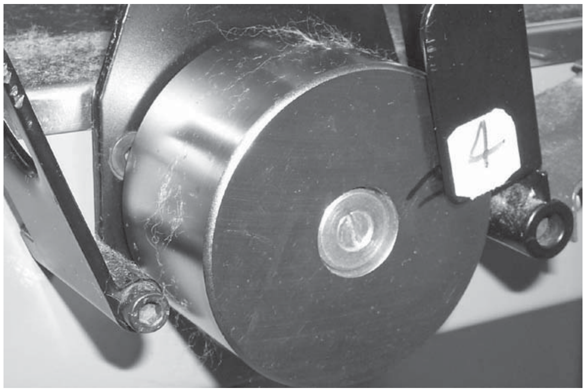


Fig. 2: Sticky deposits on ring spinning frame

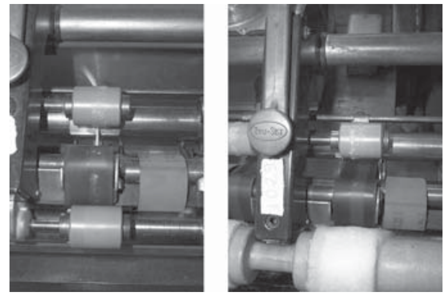


Fig. 3: Sticky deposits on the drafting section of the draw frame

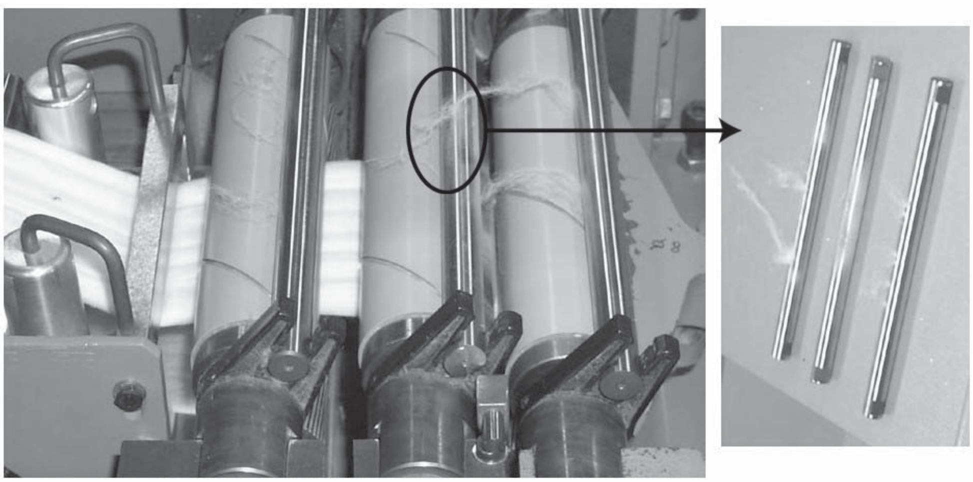
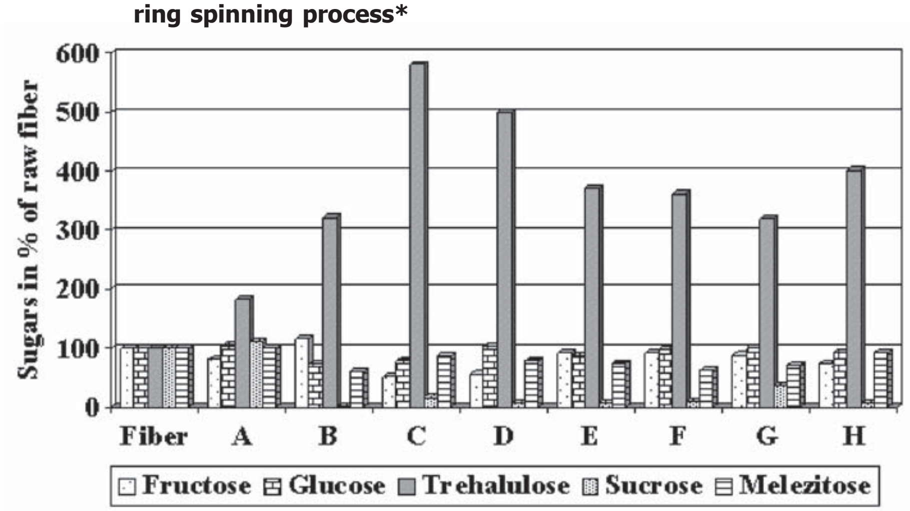
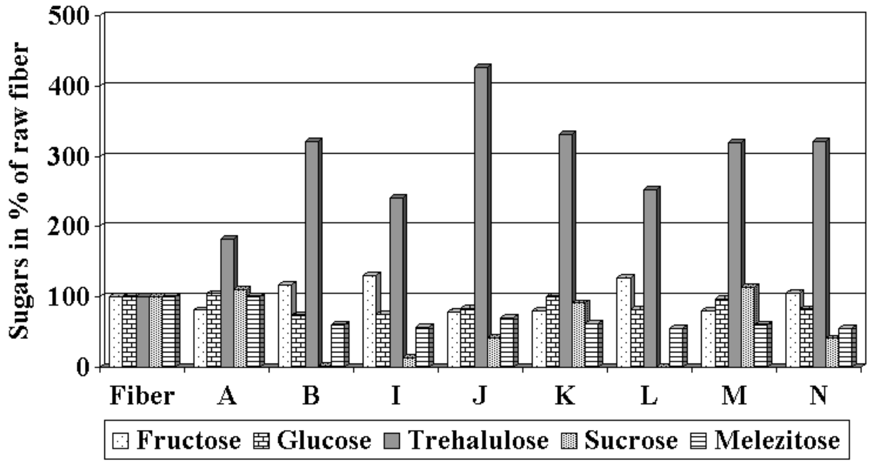


Fig. 4-a: Average HPLC results on fibers and residues collected during ring spinning process*



*** A= card flat, B = draw frame, C = ring spinning frame, D = ring spinning frame-back steel rolls, E = ring spinning frame-belt, F = ring spinning frame-center rubber rolls, G = ring spinning frame-front rubber rolls, H = ring spinning frame-front steel rolls**

Fig. 4-b: Average HPLC results on fibers and residues collected during rotor spinning process*



* A = card flat, B = draw frame-drafting zone, I = rotor spinning frame - face plate, J = rotor spinning frame-feed table, K = rotor spinning frame - rotor groove, L = rotor spinning frame-rotor housing, M = rotor spinning frame-rotor ledge, N = dust test

Table 4: Correlation coefficients between the logarithims of sugar contents on the fiber and in the residues collected rrom selected locations in spinnning*

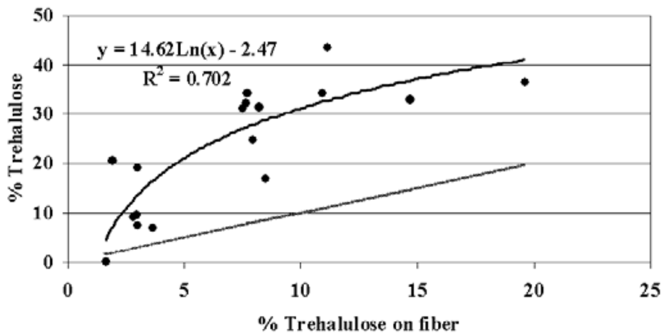
	Fructose		Glucose		Melezitose		Sucrose		Trehalulose	
Code	r^2	*p*	r^2	*p*	r^2	*p*	r^2	*p*	r^2	*p*
A	0.701 a†	0.002	0.531 a	0.028	0.612 a	0.009	0.064	0.807	0.734 a	0.001
B	0.056	0.828	0.537 a	0.026	0.214	0.408	0.133	0.612	0.607 a	0.010
C	0.004	0.986	0.449	0.070	-0.039	0.882	0.127	0.627	0.434	0.081
D	-0.021	0.937	0.543 a	0.024	0.227	0.381	0.143	0.584	0.537 a	0.026
E	-0.175	0.502	0.502 a	0.040	0.261	0.311	-0.073	0.781	0.652 a	0.005
F	0.062	0.813	0.576 a	0.015	0.339	0.183	0.144	0.581	0.746 a	0.001
G	0.199	0.443	0.747 a	0.001	0.191	0.463	0.011	0.966	0.838 a	3×10^{-5}
H	0.022	0.932	0.430	0.085	0.164	0.529	0.395	0.116	0.726 a	0.001
I	0.144	0.582	0.304	0.234	0.198	0.447	-0.301	0.239	0.512 a	0.035
J	0.039	0.882	0.782 a	2×10^{-4}	0.037	0.887	-0.228	0.378	0.888 a	2×10^{-6}
K	0.271	0.293	0.713 a	1×10^{-4}	0.209	0.420	-0.116	0.656	0.848 a	2×10^{-5}
L	0.151	0.563	0.273	0.290	0.243	0.347	None		0.491 a	0.045
M	0.108	0.680	0.427	0.088	0.299	0.244	-0.161	0.538	0.913 a	3×10^{-7}
N	0.370	0.144	0.570 a	0.017	0.129	0.621	-0.145	0.578	0.924 a	1×10^{-7}

† Coefficients of correlation followed by a letter are statistically significant with $\alpha = 5\%$.

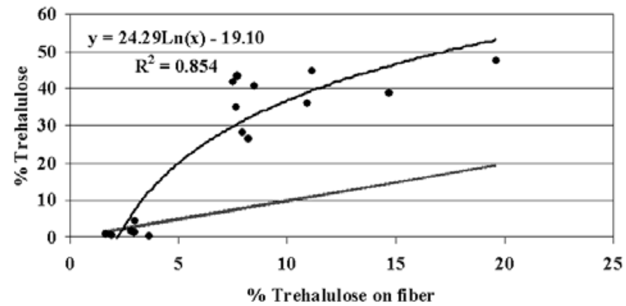
* Codes denote: A=card flat, B=draw frame-drafting zone, C=ring spinning frame-back rubber rolls, D=ring spinning frame-back steel rolls, E=ring spinning frame-belt, F=ring spinning frame-center rubber rolls, G=ring spinning frame-front rubber rolls, H=ring spinning frame-front steel rolls, I=rotor spinning frame-face plate, J=rotor spinning frame-feed table, K=rotor spinning frame-rotor groove, L=rotor spinning frame-rotor housing, M=Rotor spinning frame-rotor ledge, N=dust test

Fig. 5: Relationship between trehalulose content on fiber and trehalulose content in the residue collected from selected sections (Note: Straight line is line of equality.)

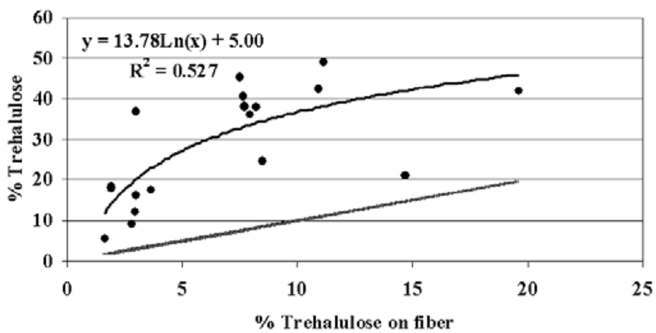
Front rubber rolls of ring spinning frame



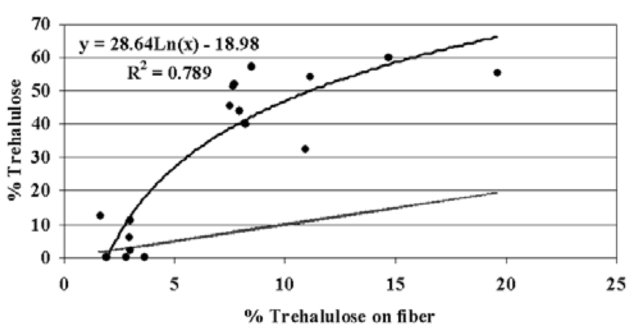
Dust collected in dust tests



Front steel rolls of ring spinning frame



Rotor feed table of rotor spinning frame



Rotor ledge of rotor spinning frame

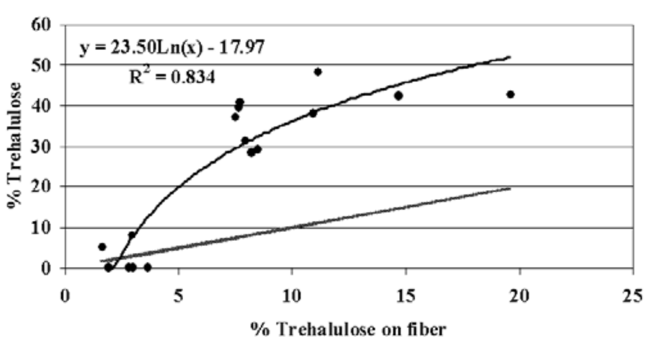


Table 5: Temperature measurements on processing equipment after machine warming

Equipment, conditions	Part	Temperature
Card		°C
23°C,	Licker-in	29
60% relative humidity	Main cylinder	34
	Flats	30
	Doffer	27
Drawing		
23°C,	Back roll	38
55% relative humidity	Middle roll	42
	Front roll	53
	Calendar roll	41
Roving		
23°C,	Back roll	26
55% relative humidity	Middle roll	28
	Front roll	31
	Trumpet	28
Ring spinning		
23°C,	Back roll	25
62% relative humidity	Middle apron	26
	Front roll	28
	Ring	27
Rotor spinning		
23°C,	Combing roll	31
55% relative humidity	Rotor	37

Fig. 6: DSC profiles of selected sugars

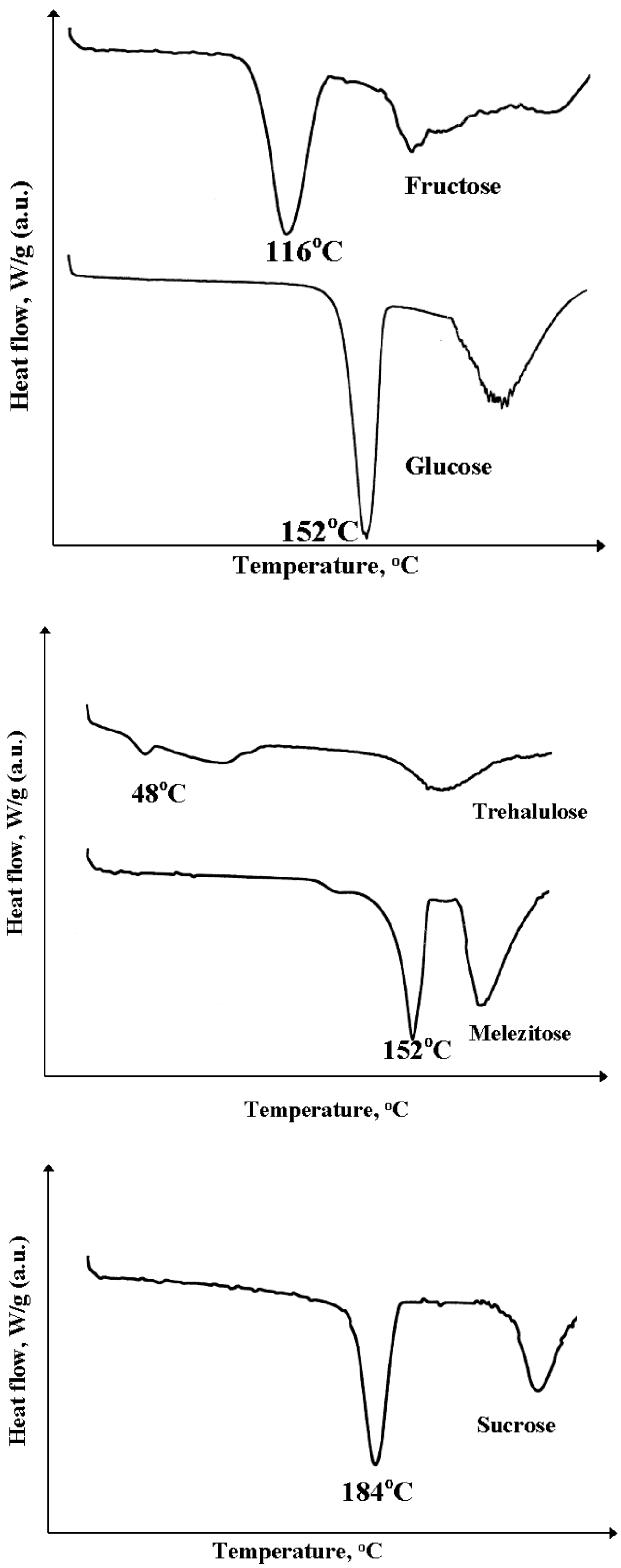


Table 6: Melting and decomposition points of selected sugars

Sugar	Melting point	Decomposition point
	-----------------°C-----------------	
Fructose	116	178
Glucose	152	210
Sucrose	184	215
Trehalulose	48	193
Melezitose	152	225

Fig. 7-a: Hydration kinetic of selected sugars at 65% ± 2% relative humidity and 21°C ± 1°C from 0 to 12.6 hours

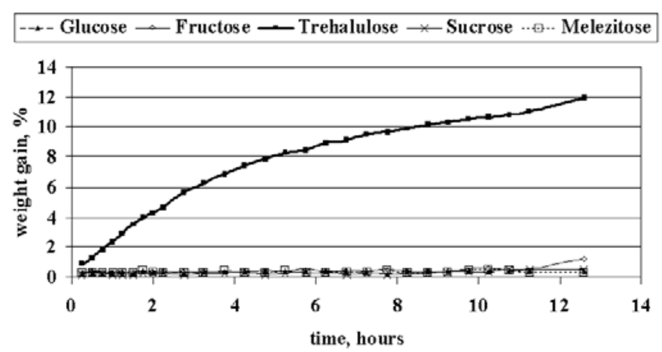
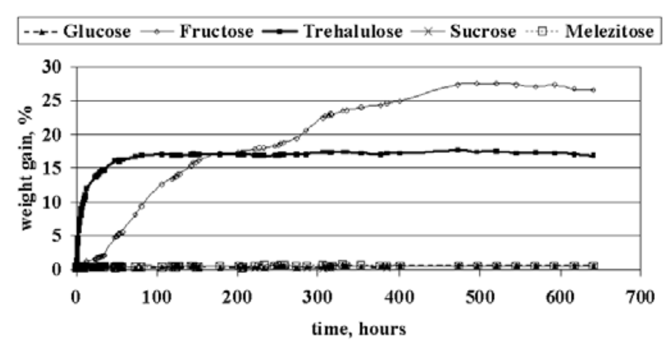


Fig. 7-b: Hydration kinetic of selected sugars at 65% ± 2% relative humidity and 21°C ±1°C from 0 to 650 hours



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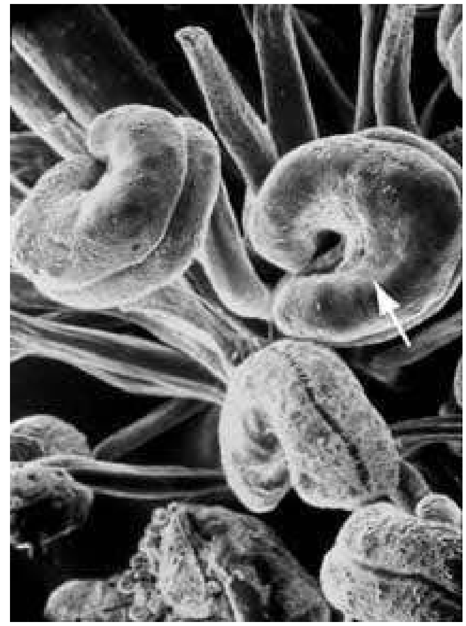

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