EXAMINATION OF CHANGES IN ELS COTTON FIBER PROPERTIES AT MAJOR STEPS OF THE SPINNING PROCESS

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Abstract

A study was done on the changes of extra long staple (ELS) cotton fiber properties at the four main stages along the spinning production line. It was found that changes in some properties were significantly related to the initial magnitudes of the properties. Thus, in the opening and blending process, relatively more damage was done to the longer and stronger cotton samples. Also, the carding, combing and drawing processes made relatively more improvement in the shorter and weaker cotton samples.

Introduction

In order to investigate changes occurring in ELS fiber properties during the spinning process, HVI and AFIS instruments were used to measure eleven selected fiber properties at four major stages along the spinning production line. This report is a companion to another being presented here at the Cotton Textile Processing Conference [Ethridge and Zhu 1997]; both rely on test results from 50 samples of ELS cottons obtained from alll over the world. The research is funded under an Advanced Technology Program grant from the Texas Higher Education Coordinating Board.

Experimental Procedures

The cotton samples contained approximately 20 kg of ginned lint, in order to carry the fiber through the spinning processes. In total, eleven fiber properties were included. These are summarized in Table 1, where symbols used for each fiber property are also given. The fiber tests are consistent with the commercially available HVI and AFIS instruments; however, the HVI leaf measurement is omitted in favor of the AFIS trash measurement.
A statistical summary of the raw fiber property measurements is included in Table 1. The data reveal a wide range of properties, reflecting the global sampling of ELS cottons.

The fiber tests were done at each of the following stages:

- Prior to opening and cleaning (on the ginned lint)
- After opening and cleaning but prior to carding (at the chute feeder)
- After carding (on the card sliver)
- After combing (on the finishing drawing sliver)

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Analysis of Directional Changes

A systematic presentation of the fiber properties is given in Figures 1 through 11. Measurements of the raw fibers were arranged in order from the lowest to the highest values. This arrangement was not altered at subsequent stages of measurement; therefore, both variations and trends in the measurements are easy to see. A discussion of these measurements is given below, with the U-test [SAS 1988] being used to determine whether statistically significant (at the 95% confidence level) changes occur between processing stages.

Micronaire (Figure 1) **-** The hypothesis that micronaire values did not change significantly cannot be rejected when comparing the raw cotton to the chute cotton. However, it is rejected when comparing measurements between the chute and the card, as well as between the card and comb. The conclusion is that the micronaire values were generally measured to be lower at the card machine and then made higher again at the comb machine. A likely explanation is that fiber samples at the card are made more dense by reduced fiber crimp and increased fiber orientation; increased density leads to lower micronaire readings. At the comb, however, the fibers become quite straight and parallel; this probably enables a higher air flow through the comb sample, resulting in an increased micronaire value[Fryer and Rust 1996 I & II; Nawar 1995].

Strength and Elongation (Figures 2 and 3) **-** Statistically significant changes occurred in both of these measurements at each subsequent stage of processing, decreasing at the chute stage and increasing thereafter. The decrease at the chute stage may be largely due to the mechanical abuse necessary for opening and blending. The tendency to break or otherwise damage some portion of the fibers increases the standard deviations for strength and elongation. A decrease in the HVI bundle strength would then be expected to follow. The carding and combing processes, however, generally remove shorter and weaker fibers, as well as decrease the crimp in all fibers [Duckett, et. al. 1994; Fryer and Rust 1996 I & II]. These changes reduce the standard deviations and increase the average levels of strength and elongation.

Length, Uniformity and Short Fiber Content (Figures 4, 5 and 6) **-** At the chute stage there was no significant change in fiber length, but length uniformity decreased and short fiber content increased. Length was again unchanged at the card stage, but uniformity increased and short fiber content decreased. After combing, length did increase significantly, while uniformity was increased further and short fiber content was decreased further. All of these results are within expectations, except perhaps the lack of change in length at the chute and card stages. If the statistical confidence level is lowered slightly to 90%, the length is judged to be significantly reduced at the chute. Nevertheless, the mechanics of the length measurement make it possible that it could remain unchanged even while uniformity and/or short fiber content do change.

Diameter (Figure 7) - The measured fiber diameter decreased significantly at each successive stage of processing[Oxenham, et. al. 1995]. This is a repeatable phenomenon on the AFIS, although it is not a logical one. It is likely due to the increased straightening and separating of the fibers at each stage.

Neps (Figure 8) - The number of neps increased significantly between the raw and the chute stages. At the card they were greatly reduced, then further reduced to very low levels by combing. Even if the number of neps was initially quite high, combing brings them almost to parity with the low-nep cottons.

Trash (Figure 9) - The trash content increased significantly at the chute then decreased significantly at each subsequent stage. The increase at the chute is largely a measurement anomaly, due to the fact that the AFIS counts the number of distinct trash particles per gram of cotton. The opening and cleaning activities tend to break largers particles into smaller ones. Thereby elevating the number to be counted at the chute. As with the nep count, the trash count is reduced to almost uniformly low levels by the combination of carding and combing.

Reflectance and Yellowness (Figures 10 and 11) - Fiber reflectance was not significantly different between the raw and the chute stages, but it increased after both carding and combing. The increased reflectance is almost certainly due to the increased orientation of the fibers. Yellowness behaved quite differently, increasing at the chute then remaining unchanged at the card and the comb. A plausible explanation for this behavior is not obvious.

A summary of directional changes for all fiber properties at the three major junctures is given in Table 2. For example, going from the raw fiber to the chute fiber results in significant negative changes in four of the properties (U, L, S and E), significant positive changes in four of them (SF, N, T and Y), and no significant changes in three (M, D and R). Over all three junctures (raw to chute, chute to card, and card to comb), a lack of significant change occurred in only five cases, with three of them being for the color measurements (R and Y).

Analysis of Fiber Property Levels versus Changes in the Levels

The extent to which changes in fiber property measurements, as measured by their first differences, at alternative processing stages are related to the magnitude of the property measurements prior to the stages is important to understanding and predicting processing performance. These relationships may be combined with the information on directional changes (re. Table 2), in order to assess how efficiently the properties are transformed by the pre-spinning processes.

The relationships may be different for the same fiber property at different processing stages; i.e., when going from raw to chute cotton, from chute to carded cotton, and from carded to combed cotton. Each of these junctures is discussed below, with nine of the eleven fiber properties given explicit consideration. The two color measurements, reflectance and yellowness, are excluded because interpretation is too uncertain.

Raw-to-Chute

A correlation matrix for each of the raw fiber properties versus each of the changes in these properties at the chute is shown in Table 2. The correlation coefficients printed in bold type identify those that are statistically different from zero at the 99% confidence level. A positive sign on the correlation coefficient for means that a larger value for the fiber property implies a larger change in the value of the associated fiber property, while a negative sign means that a larger value for the fiber property implies a smaller change in the value of the associated property.

The diagonal going from the upper right to the lower left of the table gives the correlation coefficients between each property and changes in itself. The off-diagonal numbers give correlation coefficients between each property and changes in other properties. It is noteworthy that six of the nine fiber properties are significantly and negatively correlated with changes in themselves. (The other three—L, D and T—are not significantly correlated.) Therefore, the larger the values are for these six properties at the raw stage, the larger the decrease in their values will be at the chute stage.

It is also noteworthy that changes in the uniformity index and changes in the elongation are significantly correlated with other fiber property levels. For example, the correlation between SFC and ΔU is positive, which means that the larger the SFC value for raw cotton, the larger the increase will be in U at the chute. This makes intuitive sense, because the shortest fibers tend to be removed in opening and cleaning, and their removal should improve the length uniformity.

Correlation is a key indicator of either a direct or inverse relationship between variables; however, the magnitude of the impact is better revealed by the size of the regression coefficient (i.e., the slope) between the variables. Therefore, Table 3 shows the coefficient resulting from regressing each fiber property on the change in any fiber property which has a significant correlation coefficient in Table 2. Looking at the first column of Table 3, we may conclude that

1.) A 1-unit increase in the uniformity (U) of the raw fiber is associated with a loss in uniformity of about 0.627 unit at the chute; therefore, only about .373 unit (1 - 0.627) of the increase survives to the next stage.
2.) A 1-unit increase in raw fiber strength (S) is associated with a loss in U of about 0.334 unit at the chute.
3.) A 1-unit increase in raw fiber elongation (E) is associated with a loss in U of about 1.267 units at the chute.
4.) A 1-unit increase in short fiber content (SF) of the raw fiber is associated with a gain in U of about 0.442 units at the chute.
5.) A 1-unit increase in neps (N) of the raw fiber is associated with a gain in U of about 0.006 unit at the chute.

In general we may conclude from Table 3 that a 1-unit increase in U, S, E, SF and N at the raw fiber stage will result in a decrease of each of these ranging from about a third of a unit to about two-thirds of a unit at the chute stage. Therefore, only about a third to two-thirds of the increase survives to the next stage.

Chute-to-Card

A correlation matrix for each of the chute fiber properties versus each of the fiber property changes at the card is shown in Table 4. As before, the correlation coefficients printed in bold type identify those that are statistically different from zero. In this case, only four of the nine fiber properties are significantly and negatively correlated with changes in themselves (i.e., U, SF, N and T). The changes in four of the properties (ΔU, ΔE, ΔSF and ΔN) show significant correlation with at least one fiber property level other than themselves.

The regression coefficients for each significant correlation revealed in Table 4 are summarized in Table 5. It shows, for example, that a 1-unit increase in L tends to be associated with a reduction in ΔU of 4.28 units at the card. Looking at the column for ΔN, it is seen that nep levels tend to be elevated at the card whenever the values for S, E and Mic are increased, but tend to be lowered whenever SF values are increased.

Card-to-Comb

A correlation matrix for each of the card fiber properties versus each of the changes in these properties at the comb is shown in Table 6. The bold type indicates that there are 24 instances where the correlation coefficients are statistically different from zero, with six of the nine fiber properties being significantly and negatively correlated with changes in themselves. Furthermore, the changes in six of the properties (ΔUI, ΔL, ΔE, ΔSFC, ΔNep and ΔMic) show significant correlation with at least one fiber property level other than themselves.

The regression coefficients for each significant correlation revealed in Table 6 are summarized in Table 7. The general tendencies exhibited by changes at the other processing stages are repeated here; i.e., substantial "slippage" in the transmission of desirable fiber properties through the textile manufacturing process, and substantial compromising in the balances of good and bad properties.

Conclusions

This examination of changes in ELS fiber properties at different stages leading up to yarn spinning leaves two distinct impressions:

1.) Substantial shifts occur in fiber property measurements at different stages. The opening and blending process causes a net decrease in measured fiber quality at the chute, with reductions in strength, elongation and uniformity but increases in short fiber content and neps. The carding, drawing and combing processes cause net increases in measured fiber quality, largely by eliminating the least desirable fibers from the total distribution. Measured changes in micronaire, diameter and color, while sometimes significant, appear to be due to sampling and/or measurement anomalies.

2.) There is a pervasive "leveling effect" from the processing changes. When damage is done to fiber property levels and distributions, it tends to be relatively worse on the higher quality fibers. When improvements are made in properties, they tend to be relatively greater for the lower quality fibers. The good properties tend to dissipate under the actions taken to alleviate the bad properties. Therefore, diverse fibers that are put through a typical process to prepare them for spinning will tend to emerge with smaller differences than they exhibited prior to the processing.

Each of the samples used for this study were homogeneous; i.e., they came from a single bale that had not been blended with other cotton fibers. The issues relating to changes in fiber property levels and distributions become more complex when blends of more diverse cottons are used in spinning. Studies such as this one may help provide a basis for addressing these issues.

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Table 1. The Statistics of the Fiber Properties

	Variables	Symbol	Mean	Std Dev	Min.	Max
	Uniformity (%)	U	85.639	1.594	80.8	88.3
	Length (in)	L	1.364	0.057	1.21	1.5
HVI	Strength g/tex	S	39.126	2.249	34.55	44.4
	Elongation %	E	6.849	0.558	5.83	7.9
	Reflectance (Rd)	R	69.333	3.959	63.4	79.3
	Yellowness (+b)	Y	11.079	1.384	8.3	14.1
	Micronaire (μg/in)	M	3.8	0.424	3	4.57
	Short Fiber Content (%)	SF	4.582	1.119	2.9	8.4
AFIS	Diameter (μm)	D	10.914	0.525	9.5	12.1
	Nep (no./g)	N	174.18	108.177	80	606
	Trash (no./g)	T	736.06	355.786	202	1754

Table 2. Directional changes in fiber properties at alternative stages

	U	L	S	E	SF	N	M	D	T	R	Y
Raw to Chute	-	-	-	-	+	+	*	*	+	*	+
Chute to Card	+	*	+	+	-	-	-	-	-	+	*
Card to Comb	+	+	+	+	-	-	+	-	-	+	*

+: Fiber property increases significantly.
-: Fiber property decreases significantly.
*: Fiber property does not change significantly.

Table 3. The correlations between the raw fiber properties and the changes of fiber properties from raw to chute

Raw	ΔU	ΔL	ΔS	ΔE	ΔSF	ΔN	ΔM	ΔD	ΔT
U	**-0.8**	-0.158	-0.28	**-0.608**	0.043	0.312	0.019	-0.18	0.26
L	-0.173	-0.226	-0.037	-0.073	-0.04	0.323	0.048	-0.031	0.071
S	**-0.61**	-0.088	**-0.53**	**-0.522**	-0.09	0.276	0.11	-0.185	0.165
E	**-0.567**	0.103	-0.248	**-0.698**	0.186	-0.282	0.037	0.344	0.058
SF	**0.407**	0.027	0.059	**0.415**	**-0.5**	0.054	0.009	0.239	-0.278
N	**0.514**	0.006	0.135	**0.511**	-0.1	**-0.449**	0.011	0.238	-0.171
M	-0.113	0.196	-0.15	-0.269	-0.02	0	**-0.373**	-0.251	0.131
D	-0.044	0.072	-0.133	-0.302	0.172	-0.078	-0.282	-0.274	0.184
T	-0.14	0.144	0.001	0.163	0.103	-0.013	0.04	0.079	-0.315

Table 4. The slopes of the regression equations between the raw fiber properties and the changes of the fiber properties from raw to chute

Raw	ΔU	ΔL	ΔS	ΔE	ΔSF	ΔN	ΔM	ΔD	ΔT
U	**-0.627**			**-0.128**					
L									
S	**-0.334**		**-0.292**	**-0.076**					
E	**-1.267**			**-0.418**					
SF	**0.442**			**0.121**	**-0.403**				
N	**0.006**			**0.002**		**-0.289**			
M									
D									
T									

Table 5. The correlations between the fiber property in card sliver and the changes of fiber property from chute to card

Chute	ΔU	ΔL	ΔS	ΔE	ΔSF	ΔN	ΔM	ΔD	ΔT
U	**-0.45**	-0.32	0.031	0.196	0.235	0.332	-0.075	0.205	-0.252
L	**-0.367**	-0.33	-0.121	0	-0.015	0.007	0.044	-0.06	-0.183
S	-0.258	-0.16	-0.005	0.195	**0.41**	**0.417**	-0.201	-0.233	-0.266
E	-0.108	0.036	-0.228	0.208	**0.437**	**0.425**	-0.236	0.237	0.313
SF	0.093	0.215	-0.14	-0.333	**-0.6**	**-0.6**	0.266	-0.106	0.183
N	0.213	0.301	-0.156	-0.289	**-0.48**	**-0.9**	0.265	-0.126	0.32
M	0.042	-0.05	0.345	**0.422**	0.312	**0.398**	-0.162	0.176	-0.238
D	0.349	0.227	0.298	**0.362**	-0.012	-0.036	0.086	-0.133	-0.087
T	-0.148	-0.16	0.213	0.252	0.258	0.298	0.045	0.121	**-0.99**

Table 6. The slopes of the regression equations between the raw fiber properties and the changes of the fiber properties from chute to card sliver

Chute	ΔU	ΔL	ΔS	ΔE	ΔSF	ΔN	ΔM	ΔD	ΔT
U	**-0.316**								
L	**-4.28**								
S						**15.479**			
E					**0.654**	**75.595**			
SF					**-0.349**	**-41.74**			
N					**-0.003**	**-0.641**			
M				**0.295**		**73.099**			
D				**0.184**					
T									**-0.955**

Table 7. The correlation between the fiber property in comb sliver and the changes of fiber property from card to comb

Card	ΔU	ΔL	ΔS	ΔE	ΔSF	ΔN	ΔM	ΔD	ΔT
U	**-0.538**	**-0.415**	-0.341	-0.214	**0.515**	0.255	-0.079	0.012	-0.033
L	0.274	**-0.77**	-0.183	0.119	0.087	-0.327	0.128	0.055	-0.209
S	-0.108	-0.229	-0.231	-0.089	0.215	0.146	0.112	0.278	-0.351
E	-0.337	0.052	-0.322	**-0.633**	**0.402**	**0.452**	-0.341	0.328	0.228
SF	**0.386**	-0.015	0.059	0.234	**-0.96**	**-0.417**	**0.387**	0.071	0.111
N	**0.432**	-0.188	0.138	0.256	**-0.425**	**-0.926**	**0.65**	-0.048	0.052
M	**-0.428**	0.128	-0.346	**-0.428**	**0.594**	**0.665**	-0.335	0.116	-0.107
D	**-0.494**	0.228	**-0.364**	**-0.423**	0.269	**0.546**	-0.169	-0.021	0.055
T	0.2	-0.122	-0.073	-0.011	0.025	0.053	-0.067	0.025	**-0.972**

Table 8. The slopes of the regression equations between the raw fiber properties and the changes of the fiber properties from card sliver to comb DII sliver

Card	ΔU	ΔL	ΔS	ΔE	ΔSF	ΔN	ΔM	ΔD	ΔT
U	**-0.436**	**-0.01**			**0.515**				
L		**-0.305**							
S									
E				**-0.418**	**0.517**	**20.77**			
SF	**0.335**				**-0.96**	**-12.23**	**0.053**		
N	**0.006**				**-0.43**	**-0.47**	**0.001**		
M	**-0.794**			**-0.382**	**0.594**	**41.77**			
D	**-0.645**		**-1.034**	**-0.267**		**24.19**			
T									**-0.833**

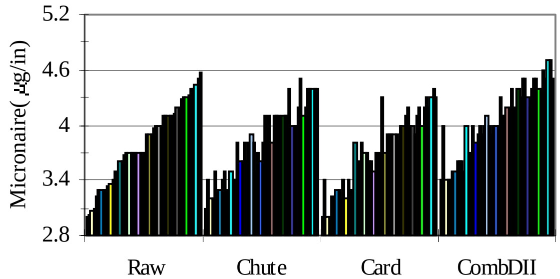


Figure 1. The changes of fiber micronaire during the spinning process

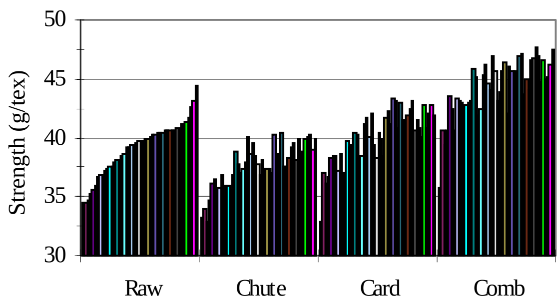


Figure 2. The changes of fiber strength during the spinning process

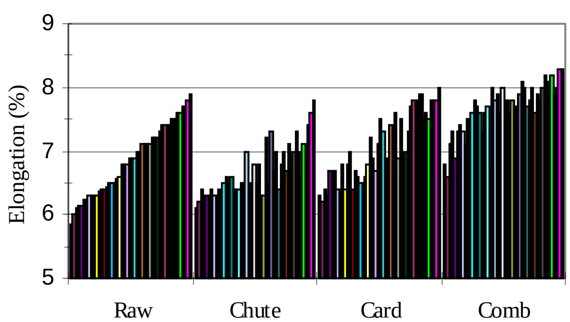


Figure 3. The changes of fiber elongation during the spinning process

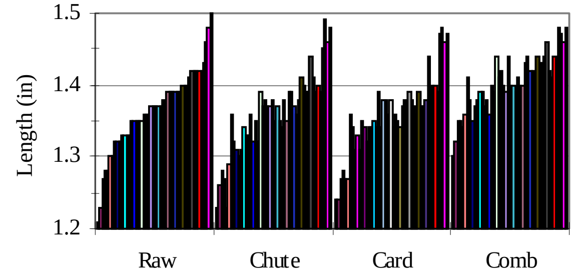


Figure 4. The changes of fiber length during the spinning process

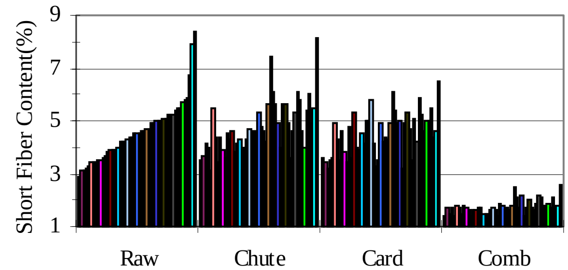


Figure 6. The changes of fiber short fiber content during the spinning process

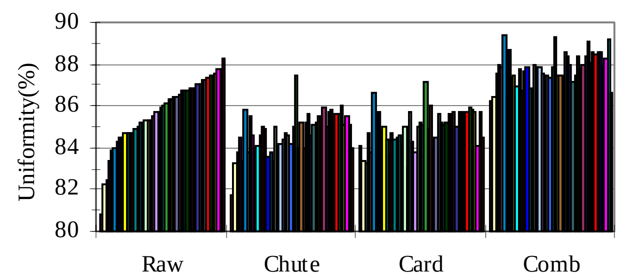


Figure 5. The changes of fiber uniformity during the spinning process

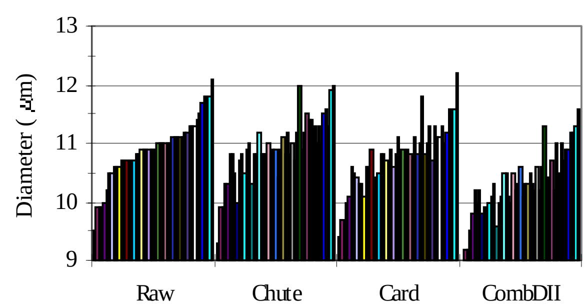


Figure 7. The changes of fiber diameter during the spinning process.

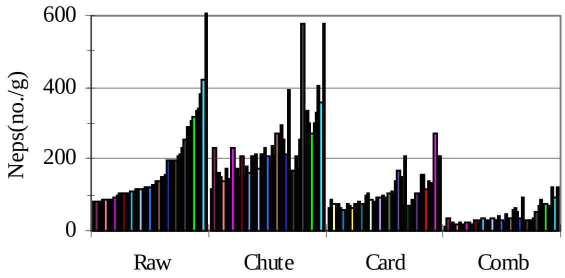
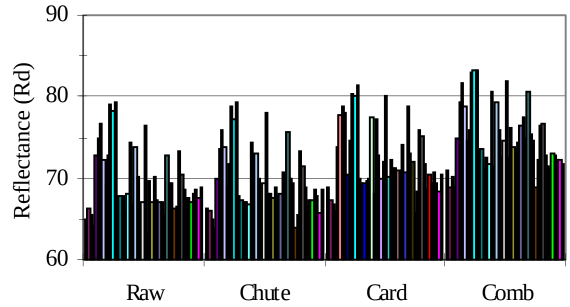


Figure 8. The changes of neps during the spinning process



Figur e 10. The changes of fiber reflectance during the spinning process.

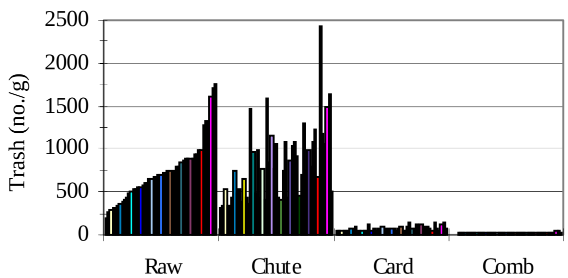


Figure 9. The changes of trash content during the spinning process

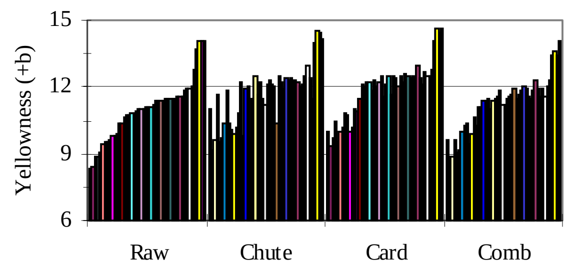


Figure 11 The changes of fiber yellowness during the spinning process.