FIBER PROPERTIES OF SAW AND ROLLER GINNED NATURALLY COLORED COTTON

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Abstract

Naturally colored cottons have economic and environmental appeal because they do not require dyeing. Naturally colored cottons do not have the same fiber length and strength as white cotton cultivars. To determine the optimal ginning process for colored fiber two Upland (*G. hirsutim*) colors were roller and saw ginned following a complete block experimental design. HVI and AFIS analysis favored roller ginning. It resulted in 0.7 mm (1/32 in) greater HVI fiber lengths and 33% fewer AFIS fiber neps compared to saw ginning. This increase in fiber value may justify the higher cost of roller ginning.

Introduction

Naturally colored cottons have a long history, dating from 3400 to 2300 BC in Mexico, 3100 BC in Peru (with fibers from 12 to 43 mm (0.5 to 1.7 in) length), 2250 BC in Egypt (19 to 22 mm (0.75 to 0.87 in) and sometime before 1200 AD in China. Russian brown cottons from the past century had good strength but lint length averaged only 19.8 mm (0.78 in), with short fiber index a low 31.1%. Colored cottons also have a history of commerce; Peru exported twelve colors from 1865 to 1937, to English manufacturers, who blended them with wool. Russia offered for sale some 700 Mg (770 ton) naturally pigmented fiber in 1945 (Vreeland, 1993).

Fiber quality and spinning tests of colored cottons enjoy a bit of history as well, with tests in the 1960s confirming data from the 1940s (Ware and Bennedict, 1962); that naturally colored cotton fibers ranged in length from 15.9 to 26.2 mm (0.63 to 1.03 in). Relative to white cottons, colored cottons were found to be weaker and shorter. Despite greater disease resistance and salt tolerance in some colored varieties, yield and lint content were lower (Conrad and Neely, 1943; Price et al., 2001). Although yields tend to be 50 to 70 percent lower than yields of conventionally grown white cotton, prices for organically grown naturally colored cotton have been higher. In 1996, organic, naturally colored brown commanded \$4.06 to 7.39 kg^{-1} (\$1.84 to 3.35 lb^{-1}) and green cotton ranged from \$8.36 to 11.02 kg^{-1} (\$3.79 to 5.00 lb^{-1}) (Katz et al., 1997). At that time base grade conventional white cottons were selling for \$1.48 to 1.74 kg^{-1} (\$0.67 to 0.79 lb^{-1}).

There has been a recent resurgence of commercial interest in naturally colored cotton since it can be made into textiles without dyeing the yarn. Consumers wishing to reduce the environmental impact of clothing are attracted by this feature. Manufacturers are attracted by the savings since dyeing can represent about 15% of the cost of an apparel item (Nimon and Beghin, 1999). To improve colored cotton fiber properties for machine processing, breeding projects are in progress in Brazil, Greece, Israel, Peru, Turkey and the former Soviet Union (Matusiak et al., 2007). Research on spinning colored cottons is being conducted in Poland (Matusiak et al., 2007).

This resurgence has, however, been a bumpy road. The production of naturally colored cottons in the United States was an estimated 1575 ha (4,000 acres) in 1992. The eco-fashion market for organic, naturally colored cotton peaked in 1993-1994, and by 1995, when world production had peaked at 11,670 Mg (12,864 tons), with 6,736 Mg (7,425 tons) grown in the U.S., many retailers had withdrawn from the market. By 1996 U.S. planting had fallen to approximately 20 hectares (50 acres) (Katz, et al., 1997).

Nonetheless, production of naturally colored cotton that can be machine spun continues. Small quantities are sold to mills in Europe and Japan. The primary difficulty US producers face today is not marketing, but finding a gin willing to process their crop. States have passed legislation to protect white cotton from contamination (California Code of Regulations, 1997; Arizona Department of Agriculture, 2005). Most gin managers feel that the required notification, separation, cleanup and inspection costs far exceed the potential revenue from ginning a small batch of colored cotton. One solution may be to dedicate a gin to processing colored cotton exclusively; this may be feasible now as a number of gins are closing because of consolidations and reduced plantings.

Objectives

The primary objective of this study is to compare fiber properties resulting from roller and saw ginning modern cultivars of naturally colored Upland (*G. hirsutim*), to help mills and producers decide which process best meets their needs. Additionally, fiber properties for two colors and two sources are compared with published historic data.

Materials and Methods

Although naturally colored Pima cottons (*G. Barbadense*) also exist, most production today is naturally colored Upland (*G. hirsutim*); only the latter species was tested. Two colors of naturally pigmented seed cotton complying with phytosanitary certification requirements were brought to Mesilla Park, New Mexico in a sealed container. The material was weighed and divided into 100 kg (220 lb) lots, four green and eight rust or reddish-brown (henceforth called "red"). After sampling for moisture content, the hand picked seed cotton was pre-cleaned in one 6-cylinder inclined cleaner and one burr-and-stick machine. No drying was used.

Two treatments, saw or roller ginning, were randomly assigned in a complete block design resulting in four replicates for red and two replicates for the green cotton. The saw gin operated under normal settings. Seed cotton final cleaning and opening occurred in a Galaxy 91 cm (36 in) wide feeder. Fiber-seed separation occurred in a Continental/Murray Double Eagle 40.6 cm (16 in) diameter 46-saw stand with seed tube; saw speed was 656 rev min^{-1}. Lint cleaning took place in a 165 cm (65 in) wide Moss-Gordon lint cleaner, with a feed roller speed of 82 rev min^{-1} and the lint cleaner saw drum turning at 1031 rev min^{-1} past five grid bars.

During roller ginning the Consolidated HGM feeder operated slowly, at 29% of normal speed. This slower speed was required for continuous smooth operation; at higher speeds seedcotton tended to choke up the ginning point. The Consolidated HGM 102 cm (40 in) wide 40 cm (15 in) diameter ginning roller speed was 121 rev min^{-1} and the rotary knife speed 417 rev min^{-1}. Stationary knife air cylinder pressure was 32,000 kg m^{-2} (45.5 lb in^{-2}). Lint cleaning occurred in a 98 cm (38.5 in) wide 40.6 cm (16 in) diameter pin-on-lug-type three lug cleaner turning at 1090 rev min^{-1}. During roller ginning, the battery condenser ran at 36% the speed it did when saw ginning.

The red and green seed cotton used in the ginning test came from one hand picked source. Additional lint samples were obtained from a second, machine harvested source. Samples from both sources were analyzed to compare fiber properties of modern, naturally colored cotton from two cultivars and two production locations with modern whites and other naturally colored cottons, where published data exists.

Two samples of lint from the first and last minute of ginning were collected at the lint slide over the bale press. Lint samples were divided into analysis samples of the appropriate weight; these were sent to the USDA-Agricultural Marketing Service-Cotton Division Classing Office in Visalia, CA for High Volume Instrument (HVI) analysis, and to the USDA-Agricultural Research Service-Cotton Quality Research Station in Clemson, SC for Advanced Fiber Information System (AFIS) analysis.

Results and Conclusions

Despite hand harvest having extended over more than a month, seed cotton moisture content was found to be reasonably uniform from lot to lot, averaging 7.5% for the green and 8.6% for the red, dry mass basis. Trash content and nep counts were low, another affect attributed to hand harvesting.

Differences by Ginning Treatment

Table 1 compares fiber properties of colored cottons for saw and roller ginning. When separated by color, HVI length increased 0.79 mm (0.03 in) and HVI staple length increased 0.79 mm (1/32 in) with roller ginning. Elsewhere a similar increase was observed for white upland cotton. Armijo and Gillum (2007) reported length increasing from 29.5 to 30.5 mm and staple length from 37.2 to 38.3 when comparing roller ginning to saw ginning. Length uniformity reported in Table 1 showed a slight improvement, but HVI fiber strength decreased with roller ginning. Again, these results are similar to those obtained from white cotton by Armijo and Gillum (2007), who saw uniformity increase from 81 to 82.8, and strength decreasing from 27.8 to 27.4 g/tex, though they report no statistical significance for the decrease in strength associated with roller ginning. With saw ginning there are more fibers broken. It is possible that the weaker fibers break preferentially, resulting in a mean increase in strength among the surviving fibers.

Table 1. Impact of roller or saw ginning on fiber properties of colored cotton.

	Both			Red			Green		
Variable	Saw	Roller	Pr>F*	Saw	Roller	Pr>F*	Saw	Roller	Pr>F*
n	12	12		8	8		4	4	
HVI Measurements									
Staple Length (mm)	25.0		0.1304	23.8	24.6	<0.0001	26.2	26.8	0.0240
Micronaire	3.39		0.8211	3.69		0.1080	2.79		0.3559
Strength (gf tex^{-1})	24.6	24.1	0.0131	24.7	24.1	0.0432	24.3		0.2002
Leaf	1.08		0.1522	1.00		1.0000	1.25		0.1340
Length (mm)	25.0		0.1083	24.0	24.7	<0.0001	26.2	26.9	0.0020
Uniformity (%)	78.7	79.8	<0.0001	78.7	80.1	<0.0001	78.9		0.1074
AFIS Measurements									
Mean Nep Size (µm)	716	769	<0.0001	713	768	0.0003	722	771	0.0008
Total Nep Count (g^{-1})	340	252	0.0005	303	229	<0.0001	416	297	0.0059
Fiber Length (mm, by weight)	22.0	22.9	0.0137	21.5	22.3	<0.0001	22.9	24.0	0.0003
Coefficient of Length Variation (% by wt.)	34.3		0.2075	33.8	32.8	0.0199	36.3		0.1130
Upper Quartile Length (mm, by wt.)	26.9		0.1258	25.9	26.4	<0.0001	27.9	28.7	0.0033
Short Fiber Content (% by wt.)	11.46	9.43	<0.0001	11.96	9.81	0.0003	10.5	8.68	0.0074
Mean Fiber Length (mm, by no.)	18.2	19.1	0.0012	17.9	18.8	0.0005	18.9	19.7	0.0033
Coefficient of Length Variation (% by no.)	44.8		0.0915	44.8	43.2	0.0125	46.5		0.6105
Short Fiber Content (% by no.)	27.2	23.9	0.0001	27.9	24.2	0.0008	25.8	23.2	0.0337
Length Exceeded by 5% of Fibers (mm)	30.5		0.2174	29.2	29.7	<0.0001	32.0	33.3	<0.0001
Trash Count (g^{-1})	828	1355	0.0165	659	940	0.0027	1170	2190	0.0005
Mean Size of all Particles (µm)	263	248	0.0253	249		0.5724	289	248	<0.0001
Dust Count (g^{-1})	725	1236	0.0112	585	853	0.0022	1010	2000	0.0003
Trash Count (g^{-1})	111		0.4537	80.2		0.0578	172		0.3890
Visible Foreign Matter (% by weight)	2.18		0.0982	1.36	1.86	0.0239	2.83	3.80	0.0242
Mean Seed Coat Nep Size (µm)	1290	1362	0.0229	1314		0.2668	1290	1410	0.0206
Seed Coat Nep Count (g^{-1})	35.1	47.3	0.0037	31.6	46.9	0.0092	45.1		0.1304
Fineness (millitex)	157		0.6660	166	163	0.0067	142		0.8439
Immature Fiber Content (%)	9.63	9.21	0.0078	9.56	9.13	0.0314	9.56		0.1268
Maturity (%)	0.826		0.1101	0.830		0.2328	0.818		0.1135

*Where there is no statistical significance (at the 0.05 level) the mean is presented.

AFIS properties that were significantly different are numerous. The most important differences were fiber length (both by number and weight basis), short fiber content (again by number and weight) and total nep count, all of which favored roller ginning. Each of these were also found to be significant in the test reported by Armijo and Gillum (2007) where length increased from 26 to 27.3 mm, short fiber content decreased from 10 to 7.83% and total nep count decreased from 316 to 219 per gram, all due to roller ginning. With roller ginning there were fewer total neps, but seed coat neps were higher. This indicates an increase in seed damage from roller ginning.

Roller ginning also results in slightly higher turnout (recovered lint as a percent of seed cotton mass); Armijo and Gillum (2007) report upland cotton turnout increasing from 34.5 to 35.8%. Combining that with improved grades, value of a 218 kg (480 lb) bale of white cotton increases $3.29 by roller ginning. It would be inappropriate to estimate the change in price for a bale of colored cotton the same way, since organic naturally pigmented lint does not trade based on the USDA-CCC loan value. It is up to individual spinning mills to estimate the increase in value based on their processing experience.

Table 2. HVI and AFIS fiber properties of hand picked roller ginned green and red specialty cottons with range of values of typical machine picked saw ginned white cottons provided for comparison only.

Variable	Green	Red	Pr > F*	White	
n	8	16		(typical)	Ref
HVI Measurements					
Staple Length (mm)	26.5	24.2	<0.0001	26.7 - 31.2	2
Micronaire	2.79	3.69	<0.0001	3.90 - 4.89	1
Strength (gf tex^{-1})	24.4		0.6924	24.0 - 33.0	1,4
Leaf	1.25	1.00	0.0377	2.93 - 3.80	1
Upper Half Mean Length (mm)	26.4	24.4	<0.0001	26.5 – 29.7	3
Uniformity, %	79.2		0.0984	80.7 - 84.6	3,4
AFIS Measurements					
Mean Nep Size (µm)	743		0.6853	697 - 743	2
Total Nep Count (g^{-1})	357	266	0.0008	164 - 278	1,2
Average Fiber Length (mm, by weight)	23.5	21.9	<0.0001	23.0 - 31.0	2,4
Coefficient of Length Variation (% by wt)	36.3	33.3	<0.0001	30.9 - 35.7	1
Upper Quartile Length (mm, by weight)	28.2	26.2	<0.0001	27.4 - 32.3	2
Short Fiber Content (% by weight)	9.56	10.89	0.0308	6.33 - 10.6	1,4
Mean Fiber Length (mm, by number)	19.3	18.4	0.0010	17.3 - 20.5	1,3
Coefficient of Length Variation (% by no.)	46.5	44.0	<0.0001	44.7 - 63.4	1,3
Short Fiber Content (% by number)	25.5		0.1382	21.7 - 35.8	1,3
Length Exceeded by 5% of Fibers (mm)	32.8	29.5	<0.0001	32.1 – 33.6	1
Total Trash Count (g^{-1})	1677	799	<0.0001	53 - 266	2
Mean Size of all Particles (µm)	269	249	0.0071	250 - 306	4
Dust Count (g^{-1})	1505	719	<0.0001	310 - 654	1
Trash Count (g^{-1})	171.5	80.2	<0.0001	67 - 111	1
Visible Foreign Matter (% by weight)	3.31	1.61	<0.0001	1.29 - 6.10	1,2
Mean Seed Coat Nep Size (µm)	1330		0.3040	689 - 1190	1,2
Seed Coat Nep Count (g^{-1})	41.2		0.2243	9.11 - 40.2	1,2
Fineness (millitex)	142	164	<0.0001	165 - 188	1
Immature Fiber Content, %	9.42		0.2159	2.84 - 4.61	1
Maturity Ratio, %	0.818	0.830	0.0023	0.832 - 0.905	1

*Where there is no statistical significance (at the 0.05 level) the mean is presented.
References: [1] Boykin (2005), [2] Holt (2004), [3] Bednarz et al. (2002), [4] McAlister (2001)

Differences between two colors and white

While these specialty cottons are not traded based on USDA-AMS Classing Office (HVI) grades, it is interesting to observe the differences between them and “typical” upland cottons. Table 2 shows HVI and AFIS fiber properties for hand picked roller ginned green and red colored cotton, and the range of values for typical machine harvested saw ginned upland white cottons found in recent publications. While different, the harvest and ginning histories are typical for each respective type of cotton.

Micronaire is strongly affected by climate and can vary from year to year. Seventy-five percent of US cotton falls between 3.5 and 4.9 (the base range) (USDA, 2001). The red cotton micronaire of 3.7 was in the premium range, the green, at 2.8, would receive a discount if it were priced using the same criteria as white cottons.

Fiber length is the property that has the greatest influence on lint value. From these comparisons the red was 80 to 90% of the average length of white cottons, the green was comparable to the lower end of the whites. From the standpoint of machine spinning, naturally colored fibers, often blended with organic Pima Extra Long Staple (ELS) to make finer yarns, are on the verge of holding their own.

Comparison to Other Naturally Colored Cottons

Lint lengths of pre-Columbian Peruvian cottons marketed today range from 12 to 43 mm (0.5 to 1.7 in) (Vreeland, 1993). Lint lengths of Nankeen brown and Arkansas green, naturally colored cottons grown in the U.S. during the colonial period, ranged from 15.9 to 26.2 mm (0.63 1.03 in) (Katz et al., 1997). Measuring methodology was not specified for these antique cottons thus comparisons may be inappropriate. Today lint length (staple) measured by an HVI classing machine is the average length of the longer half of the fibers (upper half mean length), measured by passing a beard of paralleled fibers through a sensing point (USDA, 2001).

Conclusion

Cotton from two different sources, apparently from different seed lines, both showed improvement in HVI staple length over varieties tested about ten years earlier. Despite these gains from selective breeding programs, naturally colored cottons still are not as long or as strong as white cottons grown today.

Roller ginning naturally colored cottons resulted in a 0.7 mm (0.03 in) increase in HVI length (approximately one staple) and a 32 to 33% decrease in fiber neps. Roller ginning reduced strength and improved uniformity for one color, and reduced short fiber content for both.

Roller ginning is more expensive than saw ginning. However, improvements in fiber properties and potential increases in gin turnout help to offset the added cost. Roller ginning naturally colored cottons could preserve fiber length, an important consideration when machine spinning lint that is intrinsically shorter than white cottons. Because of the premium market value naturally colored cottons enjoy, it may be worthwhile.

Disclaimer

Names are necessary to report factually on available data; however the USDA neither guarantees nor warrants the standard of the product(s), and the use of the name by the USDA implies no approval of the product to the exclusion of others that may be suitable.

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