BICOMPONENT SPINNING OF NATURALLY COLORED COTTON YARNS

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Abstract

Naturally colored cotton grows fibers in shades of green, red, and brown, instead of the usual white. Although the plants have been cultivated in many countries for thousands of years, they remained obscure because fibers from the indigenous plants could not be spun commercially. Genetic breeding has recently produced colored cultivars that can be processed on conventional textile machines. Yet, since most colored fibers remain relatively short and weak, they are usually mixed with white cotton to increase yarn strength, facilitate processing, and reduce costs. However, blending the fibers also dilutes the color intensity of the textiles, reducing their visual appeal. Thus, existing spinning methods cannot use colored cottons to their fullest advantage.

This study compares machine-spun yarns made from naturally colored cotton using conventional and ARS-patented spinning methods. Scientists from the Southern Regional Research Center have produced the first composite yarns from the fibers using a method called staple-core spinning. The method hides strong synthetic fibers in the center of the yarns by wrapping them with colored cotton. The experimental yarns look and feel like colored cotton but are stronger and more extensible than yarns spun using common methods. The superior properties and appearance of the patented yarns suggest great potential for the naturally colored cottons in a diversity of fabrics. Naturally colored yarns and fabrics do not require chemical dyeing, a benefit to the environment.

Introduction

Naturally colored cotton has existed for thousands of years and has been cultivated throughout history in countries of Asia, Africa and the Americas. The plants produce soft, beautiful fibers in rich earthy shades of green, red and brown, but these are typically shorter and weaker than white varieties. The colored cottons received little attention in the recent past because their fibers were not suitable for commercial processing. Genetic breeding has improved these cultivars and made it possible to spin them on conventional textile machines. However, the colored fibers are typically still blended with white cotton to improve yarn strength and processability or to reduce costs. Unfortunately, mixing white and colored fibers also reduces the color intensity of the products. Consequently, existing textile methods cannot take full advantage of naturally colored cotton.

Colored cotton has been grown in Louisiana for generations by the Acadians, or "Cajuns", of French descent, but their textiles were historically spun by hand. Today, scientists at the Southern Regional Research Center (SRRC) in New Orleans, Louisiana, are engaged in cooperative research to improve the properties of machine-spun textiles made from naturally colored cotton. This study compares yarns spun from naturally colored cotton blends, using conventional and ARS-patented methods. A yarn-making technology developed at SRRC known as staple-core (SC) spinning proves well suited for naturally colored cottons. These SC yarns contain an outer layer of colored cotton and an inner core of polyester staple fibers. The result is a bicomponent yarn containing two types of fibers that are securely "sandwiched" together, instead of being merely twisted together or plied.

There is a growing public interest in environmentally responsible practices and products in the marketplace today. Naturally colored cotton products have been embraced enthusiastically by niche consumer markets, despite their current limitations. The availability of superior naturally colored textiles could transform the fibers from a novelty into the mainstream market. Growers claim that colored cottons are more drought hardy and pest resistant than white varieties, and report that smaller colored crop yields are offset by higher prices [3, 4, 5]. Textiles made from these fibers do not require chemical dyeing, a costly, resource intensive process. SC yarns use less of the costly colored cotton, but involve more labor to produce. This study compares the yarns produced by the two methods but not their costs.

Materials and Methods

This study compares experimental SC yarns with conventional rotor-spun yarns as controls. All yarns were spun from the same pure fiber or from intimate blends of colored and combed white (W) Acala fiber. Blends are identified by the percentage of colored fibers in the mixtures. Yarns were produced containing 100%, 83%, 67%, and 50% levels of red (R), green (G), or mocha (M) fibers on their visible surfaces. The SC yarns contain polyester staple fiber in their cores.

A Hoechst Celanese[1], high tenacity, 1.0 denier, Trevira #121 polyester was used for the center of the SC yarns. This fiber had a staple length of 38.1 mm (1.5 in), a tenacity of 6.7 gpd (60.3 g/tex or 591.5 mN/tex) by 3.2 mm or 1/8-inch gage Stelometer, and an elongation of 23%.

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The polyester staple was processed at SRRC on a Hollingsworth[1] granular-top card at 3.15 g/sec (25 lb/hr), producing 3.88 g/m (55 gr/yd) card sliver. This material was twice drawn into 3.88 g/m (55 gr/yd) sliver and converted into 294 tex (2 hank) medium soft roving.

The other fibers were processed at the International Textile Center (ITC), per schematic drawing (Figure 1). The colored cottons were provided by B.C. Cotton[1] of Bakersfield, CA. These were blended with a white (W) combed Acala cotton, and processed into sliver and roving at designated blend levels. The W cotton had a staple length of 28.7 mm (1-1/8 in), a tenacity of 31.0 g/tex or 304.1 mN/tex (3.44 gpd), an elongation of 6.4%, and a 4.4 micronaire. HVI and AFIS fiber data is given in Table 1.

Blending, Opening, and Cleaning

The naturally colored cotton fibers were processed in pure and blended forms, taking great care to thoroughly and uniformly mix all fibers. All lots were intimately blended using a Hunter[1] Weigh Pan Hopper Feeder, with additional blending achieved by passing stock through a AMH[1] Tuft-O-Matic Volumetric Blender. Maximum opening and cleaning was performed by passing the stock through a Reiter[1] Monocylinder B4/1, an inline dust remover, two Reiter[1] ERM's B 5/5 (the first with a condenser) and then to an AMH[1] blender.

Carding

The cotton was carded on a Reiter[1] C-4 cotton card. Card settings typically used for short-staple Texas cottons were used for the R & G lots, which were run at 12.6 g/sec (100 lb/hr). The long, strong, and fine M cotton was run at 9.45 g/sec (75 lbs/hr), using settings suitable for processing synthetic fiber. Remaining lots were carded using ITC settings for Acala cotton, and were run at production rates of 9.45 g/sec (75 lbs/hr). The linear density of all card sliver was between 3.88 and 4.25 g/m (55-60 gr/yd). Quantities of fibers lost as waste was greater for colored cottons than is typical for white cottons (Table 2).

Drawing

All breaker drawing of cottons was done on a Platt Saco Lowell[1] DE-7C Versamatic drawframe with a three over four drafting system. Six ends of 4.25 g/m (60 gr/yd) card sliver was creeled, delivering 3.88 g/m (55 gr/yd) at 600 ft/min. Carded stock was drawn at eight doubling and eight draft, delivering 3.88 g/m (55 gr/yd) sliver at 6.7 m/sec (1320 ft/min). Combed stock was drawn seven ends of 4.25 g/m (60 gr/yd) at creel, delivering 3.88 g/m (55 gr/yd) at 5.03 m/sec (990 ft/min). Finisher drawing of all cottons was done on a Reiter[1] RS851 drawframe with a three over three drafting system.

Lapping & Combing

Lapping was done on a Reiter[1] Unilap E5/3 with 28 ends of 3.88 g/m (55 gr/yd) sliver at creel, delivering a 74.4 g/m (1050 gr/yd) lap weight. Combing was done on a Reiter[1] Comber E7/6 running at 4.67 nips/sec (280 nips/min), delivering 4.25 g/m (60 gr/yd) sliver. Noils removed measured 15.6% by weight.

Roving

Roving was spun on a Saco Lowell[1] Model FC-1B roving machine with a spindle speed of 23.75 rps (1425 rpm). Every effort was made to select parameters suitable for the production of uniform, medium-soft 2-hank rovings, but some lots proved to have been run with higher than optimum twist.

Rotor Spinning

Conventional open-end spinning followed common practice for a Schlafhorst[1] Autocoro SE-9 rotor spinning machine, producing Ne 16s yarns for each blend level of the colored and control cottons, at a nominal 4.8 twist multiplier. Setup and running conditions were similar to those used normally for common white cottons, using a G231 rotor at 1667 rps (100,000 rpm), with a B174DN opening roll running at 125 rps (7,500 rpm), using a KN4/TS37 navel/twist trap.

Staple-Core Spinning

The SC yarns were spun on a specially adapted Platt Saco Lowell[1] Spinomatic spinning frame with 50.8 mm (2 in) diameter rings, at a spindle speed of 140 rps (8400 rpm) and approximately 24 draft. ARS-patented spinning adds several devices to an otherwise conventional ring spinning frame as depicted in Figure 2 [11]. Condensers and spacers control and separate the multiple rovings in the drafting zone. A pivoting mechanism incorporates a grooved bar and twist control device for each spindle. The grooved bar is positioned just beyond the nip of the front rollers, where it stabilizes the fibers and facilitates yarn formation. The core fibers are confined to the groove during SC spinning, while the sheath fibers converge from either side to interlock around them. Twist is inserted near the midpoint of the groove while the fibrous array is converted into a SC yarn. The method produces bicomponent yarns containing a high-tenacity polyester core and an outer sheath of pure cotton. The resulting yarns were a nominal Ne 16s count, with an average 4.4 twist multiplier.

Results and Discussion

This study compares the properties of rotor-spun and SC yarns with surfaces containing similar blends of pure or naturally colored/white cotton blends. The authors have previously reported on the aesthetic and functional superiority of fabrics woven from unique ARS-developed SC yarns, when compared to pure cotton or cotton-blend fabrics [6, 7, 12-16]. This paper reports on the first set of SC yarns produced from naturally colored cottons during the initial phase of this project. The production and testing of other types and sizes of SC yarns continues, as does experimentation with other composite spinning methods.

Fiber properties of the white and colored cottons vary considerably (Table 1). HVI measures the staple length of the W cotton at 28.6 mm (1.13 in). The R and G cottons are very short at only 22.4 (.88 in) and 21.5 mm (.85 in), respectively; the M is the longest at 30.2 mm (1.19 in). The W and M cottons are both very strong at 31 g/tex; and the R has a tenacity of 20 g/tex, and the G is quite weak at 16 g/tex. The W cotton has a 4.4 micronaire, in contrast to the three very fine colored cottons that measure between 2.7 and 3.1 micronaire. The R cotton exhibits less fiber elongation than the W cotton, while the G and M are more extensible. HVI color readings are not meaningful for colored cottons. There was considerable variation observed in the color of the G raw fiber.

There is excellent agreement between HVI and AFIS measurements of length and fineness (Table 1). Significantly, all colored cottons reflect very high levels of IFF, a calculated property related to the distribution of fiber circularity, and commonly used as a measure of fiber maturity. However, it is debatable whether this empirically set measure is directly applicable to the maturity of these naturally fine colored fibers of low micronaire. Nonetheless, the unique characteristics of these fibers are clearly associated with their incredible softness and beautiful luster. Their fineness results in the presence of many more fibers in the cross section of colored yarns than white yarns of the same linear density. Additional investigation of fiber properties is planned.

Because colored cotton tends to be shorter and weaker than white varieties, minor accommodations must be made in processing them. The short fibers makes uniform drafting more difficult, and contribute to greater fiber losses. The nip lengths between progressive sets of drafting rollers must be set for the longest fibers, as is customary, but exerting extra pressure during processing can be helpful. Blending with longer fibers can help process the fibers and reduce costs. Combed cotton was used for the blends in this study. Some difficulties with the roving frame resulted in certain lots receiving more than optimal levels of twist. The M cotton was observed to be somewhat neppy. The rotor yarns spun without ends down.

SC spinning of some colored cotton blends required reducing the distances between drafting rollers and the use of a small diameter grooved bar. Good coverage of the core fibers in SC yarns requires a balance between yarn tension and twist control during spinning. This is a function of many fiber and machine parameters, including the spindle speed, traveler size, yarn twist, and bar placement. Optimum conditions accounted for some variation in twist levels across SC lots. The resulting core coverage of subject yarns was very good but not perfect. More recent trials have produced yarns with nearly perfect coverage, that reflect even better intensity of color.

The SC yarns in this study were one-third high-tenacity polyester in the yarn axis and two-thirds cotton on the outside (Figure 3). The experimental yarns consistently prove to be more resilient and up to 40% stronger than yarns spun from naturally colored fibers on conventional rotor-spinning machines. The greater strength and elongation of the bicomponent SC yarns is an expected consequence of their high tenacity polyester cores. However, the unique bicomponent spinning method permits the production of stronger, more attractive yarns than can be produced on rotor machines.

Among the rotor spun yarns, the G cotton series were the weakest and least extensible; the M cottons were the strongest and most extensible (Figures 4 and 5). The SC yarns reflected the reverse trend with G yarns being the strongest and exhibiting the greatest elongation and the M SC yarns having a lower break tenacity and elongation. The trend reversal is probably attributable to the greater elongation of the G than the R and M-colored cottons, respectively. However, there could be other factors involved. All yarns showed an increase in break tenacity and a decrease in color with increasing proportions of W fiber in the blends. The SC yarns with pure color surfaces were up to 40% stronger than the pure color rotor yarns, and 20 to 30% stronger than typical colored/white cotton blends.

Color measurements were taken using a Datacolor International spectrophotometer (Spectraflash 500), using daylight conditions and Chroma QC software. CIELAB data (L*, a*, and b* values) are depicted in figures 6, 7, and 8. Measurements of SC yarns were limited to pure and 83%-color surfaces. The readings reflect an increase in the lightness values as the proportion of white cotton in the blends increases. The referenced figures represent the same yarns depicted from different vantage points. Data shows greater chromaticity values for SC than common rotor-spun yarns, but this aspect will be addressed in greater depth in subsequent reports.

Summary

This study compares the properties of common yarns with those produced from naturally colored cottons using an ARS-patented method known as SC spinning. The experimental yarns contain high tenacity polyester hidden on the inside of the yarn, with varying blend levels of naturally colored cotton on the outside. The bicomponent yarns look and feel like colored cotton, but are stronger and more extensible than those spun from the same fibers on conventional machines. They also prove to be more colorful than common yarns spun from typical white/colored cotton blends. Cotton producers, the textile industry, and consumers all have something to gain by commercialization of staple-core spinning methods for use with naturally colored cottons.

Among rotor spun yarns, the G cotton series were the weakest and least extensible; the M cottons were the strongest and most extensible. The SC yarns reflected the reverse trend. All yarns showed an increase in break tenacity and a decrease in color with increasing proportions of white fiber in the blends. The SC yarns proved to be up to 40% stronger than the pure color rotor yarns, and 20 to 30% stronger than typical colored/white cotton blends. Ongoing collaborative yarn and fabric research is aimed at the eventual goal of commercial textile production. Previous studies suggested the feasibility of heat-setting SC fabrics for improved dimensional stability and laundered appearance with a minimum of chemicals [8]. It is expected that suitable methods could be determined for SC fabrics made from naturally colored cottons. Such goods would have great environmental advantages and tremendous market potential.

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Endnotes

1] Names of companies or commercial products are given solely to provide specific information, and does not imply recommendation or endorsement by the U.S. Department of Agriculture over others not mentioned.

Literature Cited

1. American Association of Textile Chemists and Colorists, AATCC Technical Manual, Research Triangle Park, NC, 69, (1995).

2. American Society for Testing Materials, Annual Book of ASTM Standards, Philadelphia, PA, vol. 7.01-7.02, (1995).

3. Apodaca, J. K., A Brief Overview of Naturally Colored and Organically Grown Niche Cottons: Production, Marketing, Processing, Retailing, Proceedings of the National Cotton Council's Beltwide Cotton Confs., pp. 1403-1407, New Orleans, LA. January 1993.

4. Brookhart, B., The Color of Money, Farm Journal, 4-5 (April 1991).

5. Johnson, C., Color Them Intrigued, Farm Journal, 11 (February 1993).

6. Kimmel, L. B., Sawhney, A. P. S., Ruppenicker, G. F., and Harper, R. J., Comparison of Staple-Core and Intimate-Blend Fabrics Before and After Durable Press Treatments, Textile Chemist and Colorist 26 (3), 22-25 (March 1994).

7. Kimmel, L. B., Sawhney, A. P. S., Ruppenicker, G. F., and Harper, R. J., Unique Staple-Core and Conventional Cotton-Blend Fabrics with Durable-Press Finish, In Kennedy, J. F., Phillips, G. O., and Williams, P. A., (eds.) Cellulosics, Ellis Horwood, NY, 205-211 (1993).

8. Kimmel, L. B. and Sawhney, A. P. S. Evaluation of Heat Stabilized Staple-Core Knits. Proceedings of the National Cotton Council's Beltwide Cotton Confs., pp. 1436-1440, San Antonio, TX. January 1995.

9. Kimmel, L. B. and Sawhney, A. P. S. Selected Properties of Predominantly Cotton Staple-Core Knitted Fabrics. Textile Research Journal. 65(10):587-592 (October 1995).

10. Kohel, R. J. Genetic Analysis of Fiber Color Variants in Cotton. Crop Science. 25:793-797 (September-October 1985).

11. Sawhney, A. P. S., et. al., U.S. patent nos. 4,922,701 (1990), 4,976,096 (1990) and 4,961,306 (1990), and pending patent nos. 07/376,479, 07/603,504, 08/022,207, 08/102,932, and 08/195,429.

12. Sawhney, A. P. S., Harper, G. F., Robert, K. Q., and Ruppenicker, G. F., Finishing and Properties of Fabrics Produced with Polyester Staple-Core/Cotton Wrap Yarns, Textile Research Journal 61 (7), 393-397 (July 1991).

13. Sawhney, A. P. S., Harper, R. J., Ruppenicker, G. F., and Robert, K. Q., Comparison of Fabrics Made with Cotton Covered Polyester Staple-Core Yarn and 100% Cotton Yarn, Textile Research Journal 61 (2), 71-74 (February 1991).

14. Sawhney, A. P. S., Radhakrishnaiah, P., and Tejatanalert, S., Handle and Comfort Properties of Woven Fabrics Made from Random Blend and Cotton-Covered Cotton/Polyester Yarns, Textile Research Journal 63 (10), 573-579 (October 1993).

15. Sawhney, A. P. S., Robert, K. Q., Ruppenicker, G. F., and Kimmel, L. B., Improved Method of Producing a Cotton Covered/Polyester Staple-Core Yarn on a Ring Spinning Frame, Textile Research Journal 62 (1), 21-25 (January 1992).

16. Sawhney, A. P. S., Robert, K. Q., and Ruppenicker, G. F., Device for Producing Staple-Core/Cotton-Wrap Ring Spun Yarns, Textile Research Journal 59 (9), 519-524 (September 1989).

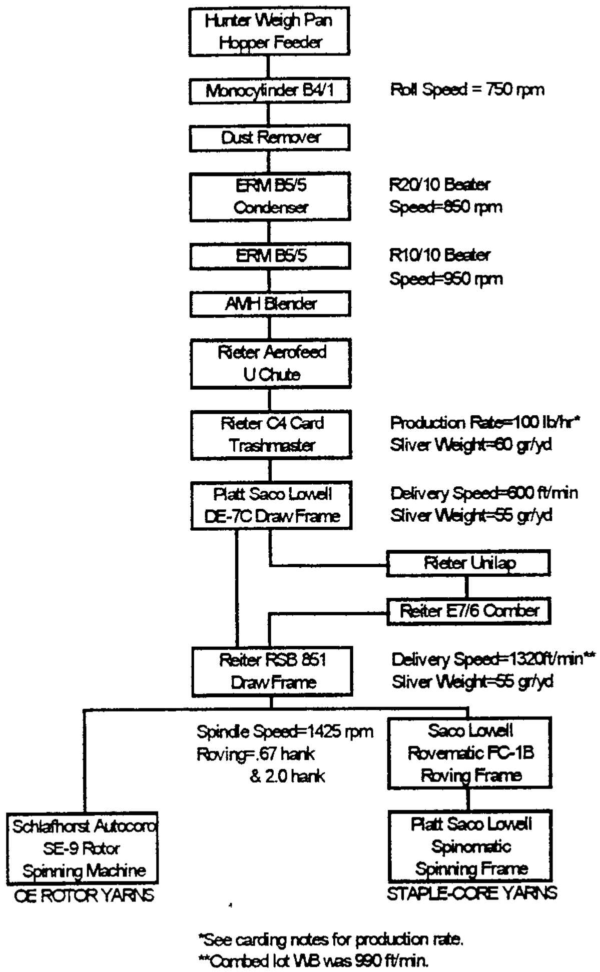


Figure 1: Processing Schematic.

Table 1: HVI/AFIS FIBER DATA

Item	White Acala	Red	Green	Mocha
Micronaire	4.4	3.1	2.8	2.7
Length	1.13	0.88	0.85	1.19
U.I.	83	80	80	81
Strength	31	20	16	31
Elongation	6.4	5.8	7.2	6.8
Leaf Index	2	2	2	2
RD	78	67	59	64
+B	7.6	9.8	9.2	9.8
Color Index	31.2	42.2	63.1	53.1

ID	L(w)	L(w)CV	SFC(w)	UQL(w)	IFF	FFF	MICRONAFIS
WD	0.98	35.7	10.6	1.22	16.88	22.34	4.084
WB	1.03	31.3	5	1.24	11.46	17.43	4.783
R	0.81	36.5	14.3	0.98	22.21	19.29	3.531
G	0.78	37.5	15.7	0.94	25.76	25.18	2.731
M	0.95	38.5	12.5	1.21	28.39	37.94	2.715

Table 2: WASTE DATA

SAMPLE	BLEND	BLOWROOM	CARD	TOTAL
1	100% W	1.88	3.24	5.12
3	100% R	6.16	5.80	11.96
4	100% G	15.92	7.83	23.75
5	100% M	8.13	6.91	15.03
7	83% R	3.96	4.58	8.54
8	83% G	9.01	6.77	15.78
9	83% M	5.00	6.20	11.20
10	67% R	3.80	4.90	8.70
11	67% G	9.95	7.50	17.45
12	67% M	5.94	7.66	13.59
13	50% R	4.51	5.76	10.28
14	50% G	11.42	7.57	18.99
15	50% M	6.42	6.25	12.67

Figure 2: FILAMENT-CORE SPINNING

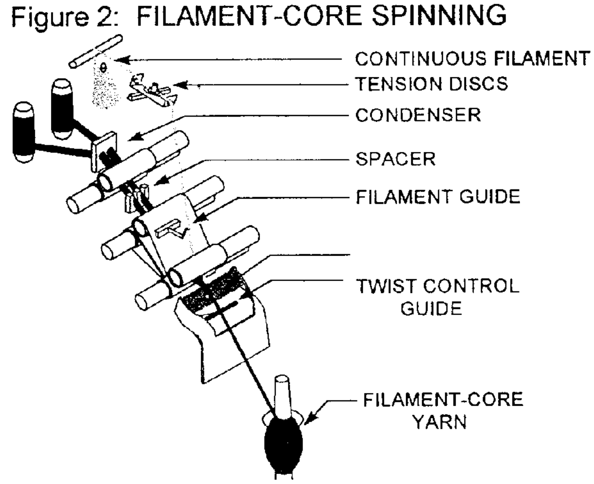
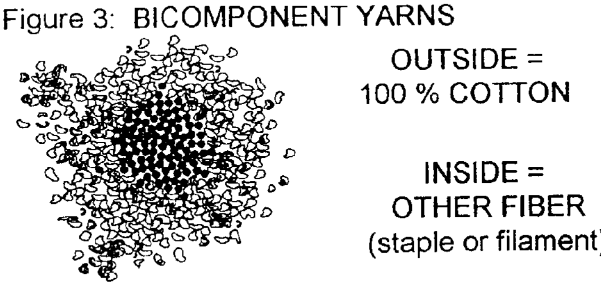


Figure 3: BICOMPONENT YARNS



Patented cotton-rich textiles look and feel like cotton, but benefit from the strength or other desired properties of the selected core fiber

Figure 4: TENACITY vs. COLOR

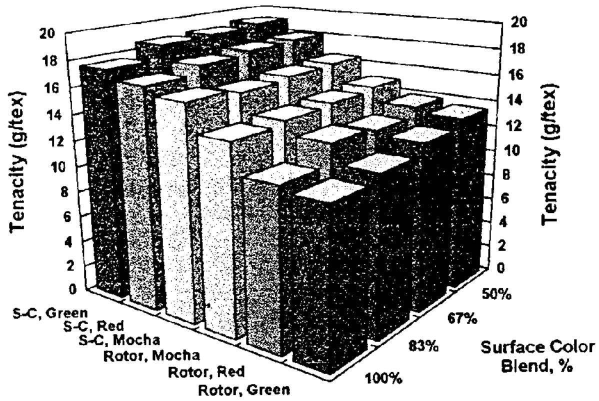


Figure 5. ELONGATION vs. COLOR

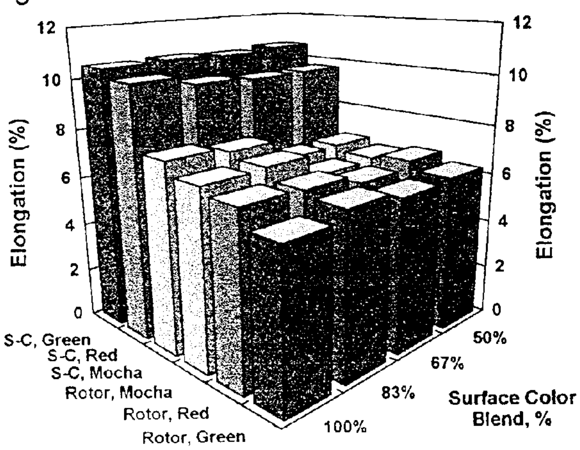


Figure 6: GREEN YARN DATA.