THE RELEVANCE OF COLOR GRADE TO YARN MANUFACTURING

Marinus H.J. van der Sluijs
Textile Technical Services
Geelong, Victoria, Australia

Abstract

This study was undertaken to establish the relevance of color grade of cotton fiber, as determined either visually or objectively, to the cotton spinning industry. Bales of cotton with different color grades e.g., Middling, Strict Low Middling and Low Middling were processed into medium and fine count carded and combed ring-spun yarns as well as fine count rotor-spun yarns.

The results from this study showed that from a yarn processing point of view there were no significant differences in yarn and processing performance between Middling, Strict Low Middling and Low Middling grade cotton with similar trash grade and HVI properties. It is thus suggested that there should be less emphasis on color and more emphasis on the objective measurement of the physical fiber properties, such as length, micronaire and strength, that would assist spinners in processing yarns with the required quality at acceptable processing performances.

Introduction

Cotton, being a natural agricultural product, differs widely from growth to growth, crop to crop, lot to lot, bale to bale, within a bale and even fiber to fiber. In view of this and the important effect which variations in fiber properties have on processing performance, cost, and product quality, it is of crucial importance that such variations in fiber properties be determined and quantified.

In order to eliminate price differences between markets, provide a means of settling disputes and make the grower more aware of the value of their product, the United States Department of Agriculture (USDA-AMS) established uniform cotton standards. Since the early 1900's this subjective classification of cotton according to established Universal Upland and American Pima Grade Standards has been used to market and sell cotton worldwide. In some instances, cotton is also sold on physical grades and shipper types represented by actual samples, which are used for reference purposes against the shipped cotton. These standards or grades are primarily based on color (color grade), visible trash (leaf grade) and preparation (degree of smoothness or roughness of the cotton sample). The accent on these properties often force gins to over clean the fiber since this results in a higher grade and subsequently a better price for the cotton grower.

With the increasing demands of modern spinning, the cost of raw material, and the increasingly competitive global market there was a need to determine rapidly and accurately those cotton fiber quality parameters which affect processing performance and yarn quality in a cost-effective way on large numbers of bales of cotton. This led to the development of high-volume automatic testing systems. These systems, termed High Volume Instruments (HVI™), provide objectively measured information as a supplement to the traditional way of cotton fiber quality determination and classing. These instruments also provide information on color in terms of reflectance (Rd) and yellowness (+b) as well as the resultant color grade. Extensive studies have shown that visual and instrument classing do provide similar results and hence the color of the entire US crop has been exclusively determined by HVI instruments since 2000 (Anon 2000).

Despite the introduction of HVI instruments and the undeniable value and significance of the information provided by these instruments; Classing Grade still plays an important part in the marketing and pricing of cotton with growers still severely discounted if they do not achieve base grade. Indeed, a study concluded that on average at 30%, color had the highest contribution to the price of cotton, followed by cleanliness/trash at 23%, micronaire at 22%, followed by length at 20%, with strength at 5% (Chakraborty, Ethridge et al. 2000). Other studies found that the textile industry paid 0.38 to 1% more for cotton that was 1% less gray and 0.13 to 0.63% for cotton that was 1% less yellow, i.e., brighter (Chakraborty and Ethridge 1999, Ethridge, Swink et al. 2000). Indeed, it has been shown that in Australia the difference between a Middling (31) and Strict Low Middling (41) color grade can result in up to US$760 loss per hectare for a grower (McVeigh 2017).

The commercial accent on grade often encourages gins to aggressively clean the fiber in the search for a higher grade and subsequently a better price for the cotton grower (van Doorn 1986). However, color and trash grades, on their own are a poor indicator of the true spinning value of the fiber. Indeed, some spinning mills offer price premiums for cotton that is harvested, ginned, and shipped to their strict specifications, i.e., custom ginned.

A previous study (van der Sluijs and Gordon 2005) showed that if minimum cleaning is done at the gin, it will result in cotton with a higher dust and trash percentage and consequently a lower (i.e., better) classing grade. However, fiber properties from a mill processing performance perspective such as staple length, length uniformity, short fiber and nep content were dramatically improved. The study also showed that modern opening and cleaning equipment can extract increased trash levels with ease.

The aim of this study was to look at the importance and relevance of Color Grade (CG) to modern spinning mill quality and processing performance requirements.

Methods and Materials

Three bales were selected and purchased to conduct the trial. The variety used for this trial was Sicot 80, a widely adopted conventional variety at that time (Reid 2002) and grown under commercial growing conditions in the Gwydir valley of New South Wales, mechanically harvested and saw ginned at a gin in Moree under commercial ginning conditions. The three bales were chosen from one large field that produced 474 bales. Due to the cool and wet season (Stiller, Bange et al. 2008) the field produced bales with three color grades (CG); 72.8% SLM (41), 26.6% M (31) and 0.6% LM (51) all with a leaf grade of 5. Bales were chosen at random with similar HVI fiber properties in terms of length, strength, micronaire and trash content.

These bales were processed at CSIRO's cotton mill in Geelong into yarn counts normally associated with Australian cotton e.g., medium, and fine count yarns in the range of 30; 40 & 50 Ne ring spun carded and combed yarns (van der Sluijs and Johnson 2011). Although, Australian cotton is not commonly used for the production of rotor yarns, fine count 30 & 20 Ne yarns were also produced.

Fiber Testing

Classing samples, from opposite sides, of each bale were collected at the gin after bale formation, with all these bale samples subjected to objective measurement, as per ASTM D5867 (ASTM 2012a), using an Uster® Technologies AG, HVI 1000 (Knoxville, TN). Two sub samples of each sample were evaluated for fiber length in terms of Upper Half Mean Length (UHML) in inch, length uniformity (UI%), short fiber index (fibers shorter than 0.5 inch) (SFI%), elongation (EL%), bundle strength in g tex^{-1} (STR), micronaire (MIC) as well as for color in terms of yellowness (+b), reflectance (Rd) and trash in terms of leaf count, % area and leaf grade.

Visual classing of the lint was conducted to determine color (CG) and visible trash (LG) according to the Universal Upland Grade Standards as established by USDA-AMS, as per ASTM D1684 (ASTM 2012b).

Fiber fineness was determined using a CSIRO, Cottonscan instrument (Geelong, VIC), which determines fiber fineness (linear density) by measuring the length of fiber in an accurately weighed specimen of fiber snippets (Abbot, Hequet et al. 2011). Combined with an independently measured micronaire value from the HVI, the average fiber maturity was calculated using Lord's empirical relationship between micronaire, maturity ratio and fineness (Lord 1956).
Samples were also subjected to testing via the Uster® Technologies AG, Advanced Information System instrument (AFIS PRO) (Knoxville, TN). Three sub samples, of 5000 fibres, were tested of each sample to determine total (TN), fibre (FN) and seed-coat neps (SCN), total trash (TT), trash count (TC), dust (DC) and nep (NS), seed-coat nep (SCNS) and trash (TTS) size in micrometer (µm) as per ASTM D5866 (ASTM 2012c).

All fiber samples were conditioned under standard conditions of 21+/-1°C and relative humidity % of 65+/-2 as per ASTM D1776 (ASTM 2015a), prior to testing.

Yarn Manufacturing

The bales were processed under commercial conditions at CSIRO's cotton mill in Geelong. One hundred and sixty kilograms of fiber from each bale was processed into ring-spun carded and combed yarns. The remainder of the cotton was processed into carded rotor-spun yarns. In all cases machines were set to industry standard settings. Production speeds were kept constant throughout the trial but machine settings i.e., draft distances, were optimized as is accepted practice in high-quality spinning mills. All ring-spun yarns were wound on a Schlafhorst AC 238 winding machine and cleared, using standard clearer settings.

Figures 1 to 3 summarize the processing steps and equipment used to convert the cotton fiber into yarn.

Opening and Cleaning
Trützschler Blowroom incorporating
Bale opener CS, Cleanomat CXL – 3 and Material Reserve MSL 1200

Raw

Machines	*Process*	*Technical Details*
Trützschler DK 903	Carding	Production rate = 15 kg/hr Sliver weight = 5000 tex
Trützschler HSR 1000	Drawing 1st Passage	Production rate = 90kg/hr Sliver weight = 5000 tex
Trützschler HSR 1000	Drawing 2nd passage	Production rate = 72 kg/hr Sliver weight = 4000 tex
Zinser 660 - FU	Roving	Spindle speed = 10 kg/hr Roving weight = 620 tex
Zinser RM 350	Ring Spinning	Spindle speed = 12000 rpm Twist Factor = 4.0

Yarn

Figure 1. Yarn processing route for carded ring-spun yarns

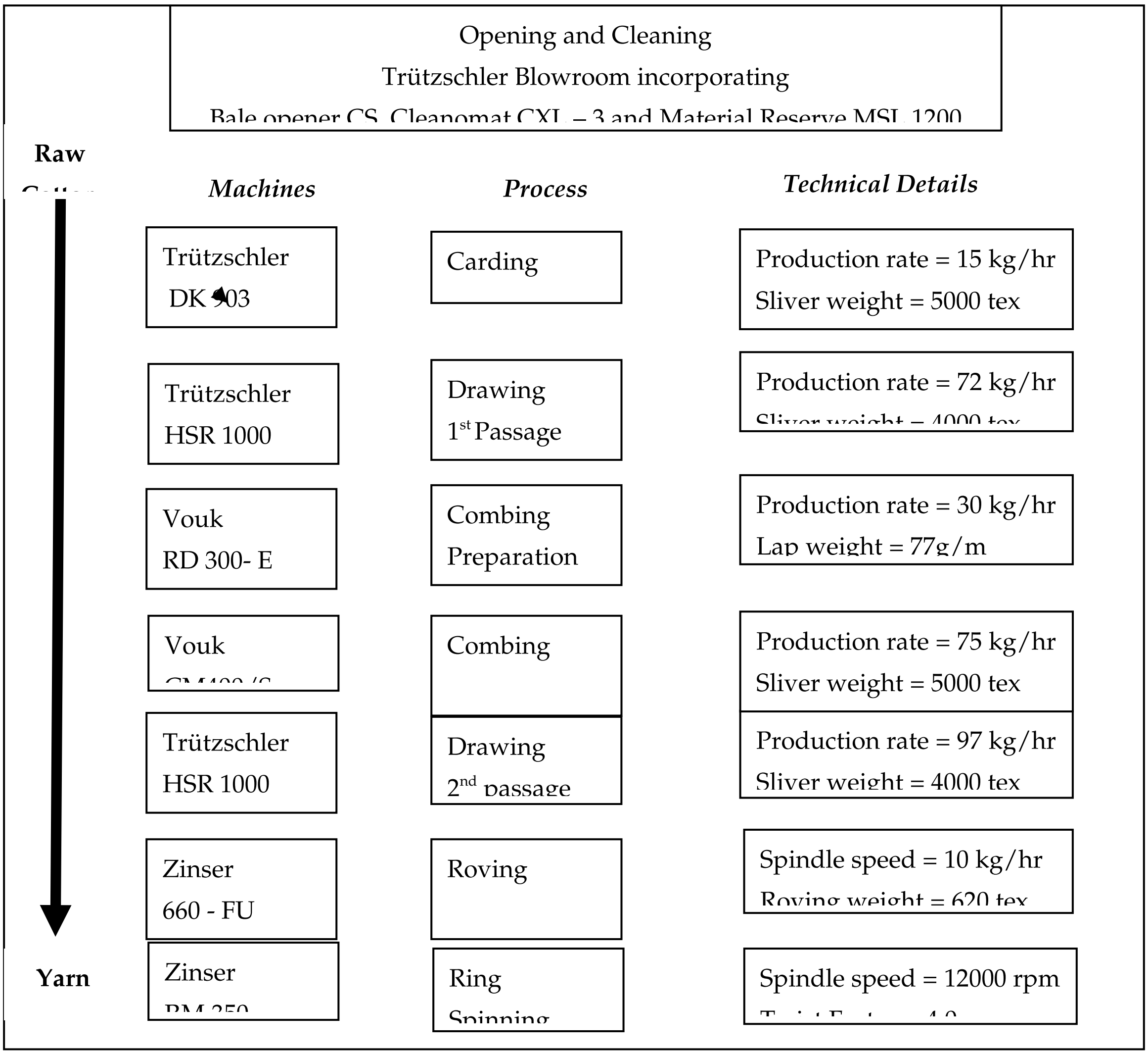

Figure 2. Yarn processing route for combed ring-spun yarns

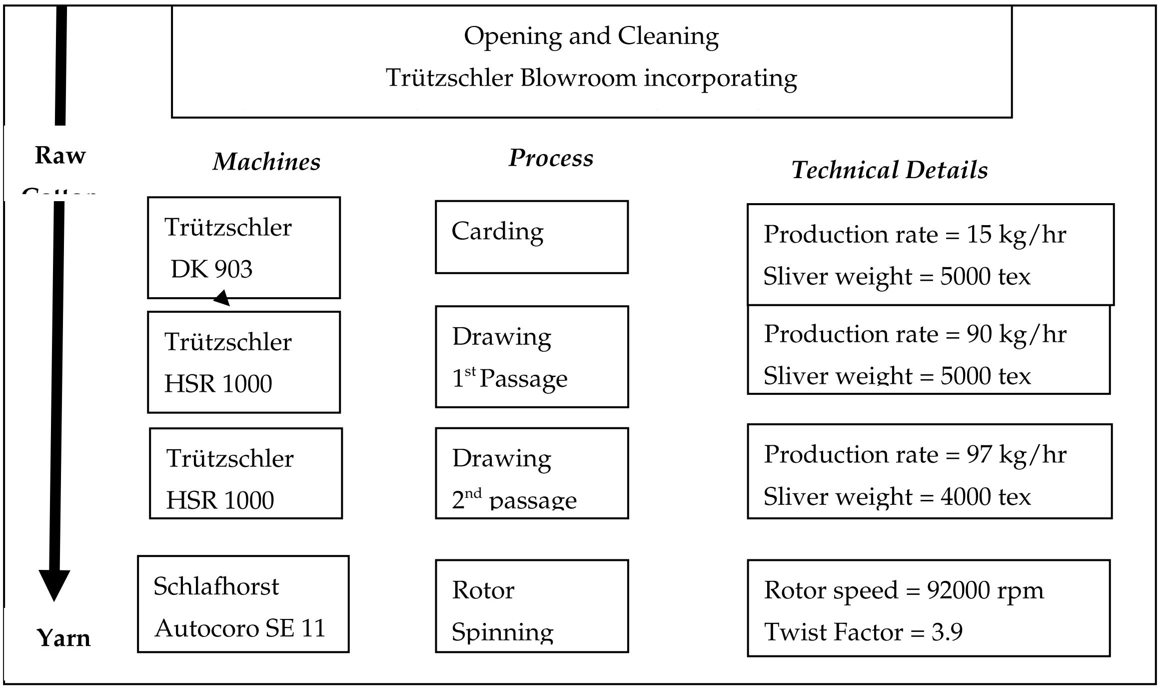

Figure 3. Yarn processing route for rotor-spun yarns

Under normal circumstances the trash, dust and impurities removed during opening, cleaning, and carding are transported by air for filtration. In this trial a Trützschler BR-WC Waste Box Collector (WAC) was connected to the various extraction points of the Cleanomat cleaner and carding machine with the waste from the CS and MSL machines transported to the coarse filter. The amount of noil extracted during combing for each CG was determined using the noil control program on the Vouk combing machine.

Yarn Testing

Spun yarns were conditioned for 24 hours under standard conditions of 21 +/-1°C and relative humidity % of 65 +/-2 as per ASTM D1776 (ASTM 2015a). Yarns were tested for linear density (count) as per ASTM D1907 (ASTM 2018), twist as per ASTM D1423 (ASTM 2016), evenness (U%), and imperfections (thin/thick/neps per km) using an Uster® Technologies AG, 4-SX evenness tester (Uster, Switzerland) as per ASTM D1425 (ASTM 2014). Tensile properties (strength in cN/tex and % elongation) were determined using the Uster® Technologies AG, Tensojet 3 strength tester (Uster, Switzerland) as per ASTM D2256 (ASTM 2015b), which simulates the load on yarns during modern high speed weaving. Yarn samples for testing were collected from the same spinning positions to allow for the accurate comparison of results.

The number of end breakages during spinning was assessed as it is an important indicator to determine whether production levels and quality standards can be achieved.

The results for the various yarns produced on the three spinning systems will be provided as figures with the average values as well as the y-error bars of one standard deviation giving an indication of the variation.

Discussion of Results

Fiber Quality

The cotton chosen for this study was better than the Australian base grade in terms of HVI parameters (UHML e 1.13 inch, UI% e 80, strength e 29 g tex^{-1} and G5 micronaire in the range of 3.5 to 4.9 - see Table 1. Although still within the G5 range the average micronaire value of 3.5 was on the low side but not unexpected as the season was one of the mildest (coolest) seasons on record resulting in the crop taking longer to mature and resulting in low micronaire values (Stiller, Bange et al. 2008). At a maturity ratio of < 80 the fiber used for this trial can be considered as immature (Lord and Heap 1988) - see Table 2. This low fiber maturity resulted in the creation of neps during the ginning process resulting in high fibrous nep content, above the 250 neps/gram preferred by spinners (van der Sluijs and Johnson 2011), as fibers were prone to bending and buckling (van der Sluijs and Hunter 2016) - see Table 2.

Table 1. Average fiber properties as measured by HVI and visual assessment per CG

CG	MIC	UHML (inch)	UI (%)	SFI (%)	STR (g tex^{-1})	EL (%)	Trash			Color		Visual	
							Leaf	% Area	Count	Rd	+b	CG	LG
M	3.5	1.22	82.1	8.4	32.0	5.4	4	0.50	63	80.4	6.8	31	5
SLM	3.5	1.21	82.0	8.5	32.1	5.9	4	0.60	74	80.3	6.4	41	5
LM	3.5	1.20	81.2	9.0	31.7	5.8	6	0.90	97	79.0	6.5	51	5

Table 2. Average fiber properties as measured by AFIS, Cottonscan and calculated MR per CG

	AFIS										Cottonscan	Calculated
CG	TN g^{-1}	FN g^{-1}	SCN g^{-1}	NS µm	SCNS µm	TT g^{-1}	TC g^{-1}	DC g^{-1}	TTS µm	VFM %	FIN mtex	MR
M	457	425	32	710	1002	816	122	694	309	1.87	172	0.73
SLM	412	375	37	713	1058	802	114	687	303	1.98	168	0.74
LM	379	344	35	700	988	874	138	736	307	2.07	170	0.73

Fiber Waste

Considering that the trash results as determined by HVI and AFIS as well as the visual leaf grade were high, the amount of trash extracted during the opening and cleaning process was generally low (< 3%) (Klein 2014a), with the majority of the trash extracted by the carding machine. The amount of trash extracted was similar for the M and SLM bales with the amount of trash extracted for the LM somewhat lower - see Table 3.

The amount of noil removed during the combing process was high (noil percentage > 22% is rare and is generally used only for the production of superfine yarns) (Klein 2014b). This was in all likelihood due to the fact that the fiber was immature, resulting in high fibrous nep content.

Table 3. Percent Trash and Noil extracted

CG	**Waste %**			**Comber**
	Opening & Cleaning	**Carding**	**Total**	**Noil %**
M	0.90	4.95	5.85	23.6
SLM	0.99	4.24	5.23	23.9
LM	0.78	3.42	4.20	25.1

Yarn Results

Ring-spun carded

The results for yarn evenness, imperfections, yarn strength and elongation are shown in Figures 4 - 9. The yarn evenness results show that although there were variations in the yarn results these variations were not significant. Interesting the evenness, thin places and neps for the coarser 30 Ne yarn produced from the SLM cotton was significantly higher than the results for the M and LM cotton. This may be related to issues with setting up the machines with the ends down results not affected - see Table 4. Similarly, the strength and elongation results show that although there were variations in yarn strength and elongation these variations were not significant- see Figures 8 & 9.

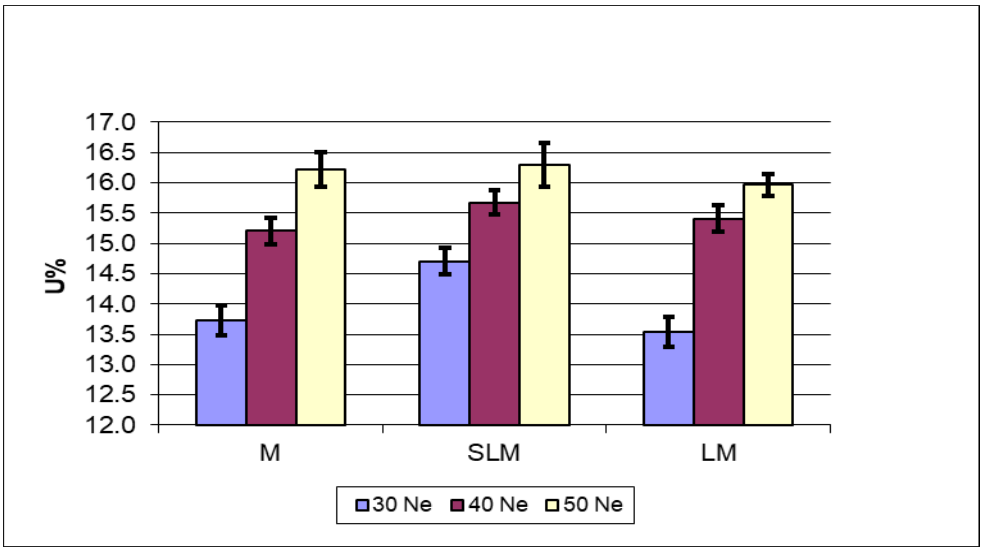

Figure 4. Evenness results for ring-spun carded yarns

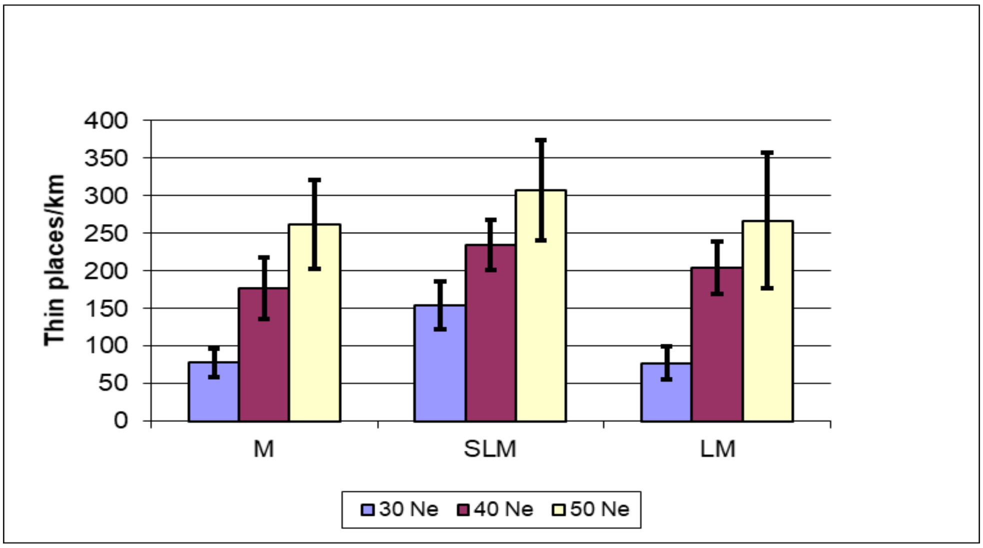

Figure 5. Thin places for ring-spun carded yarns

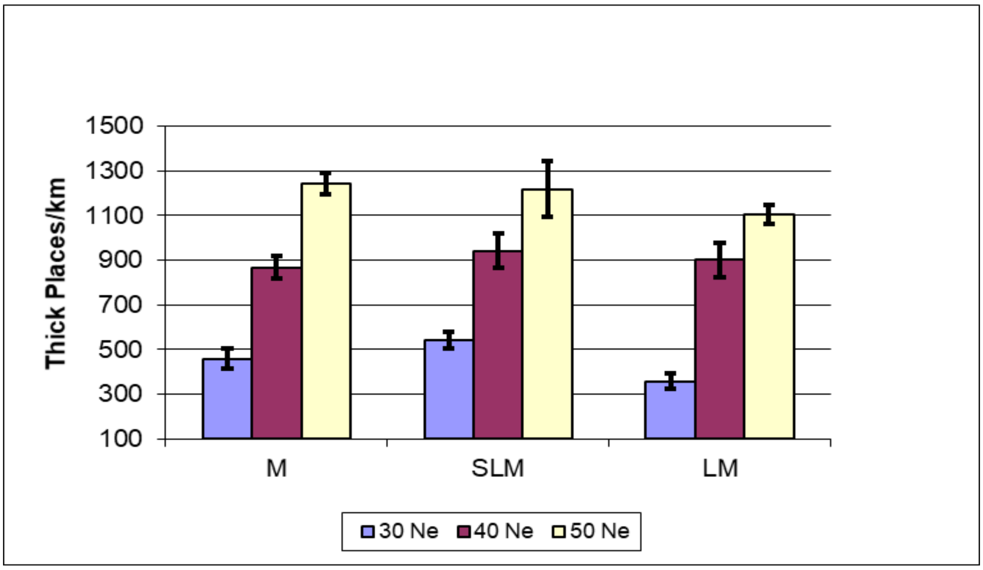

Figure 6. Thick places for ring-spun carded yarns

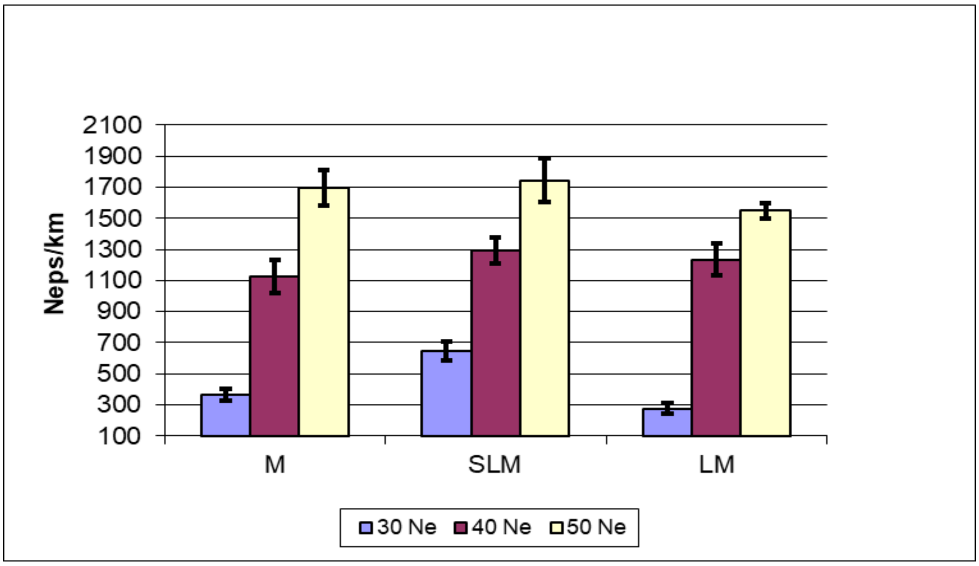

Figure 7. Neps for ring-spun carded yarns

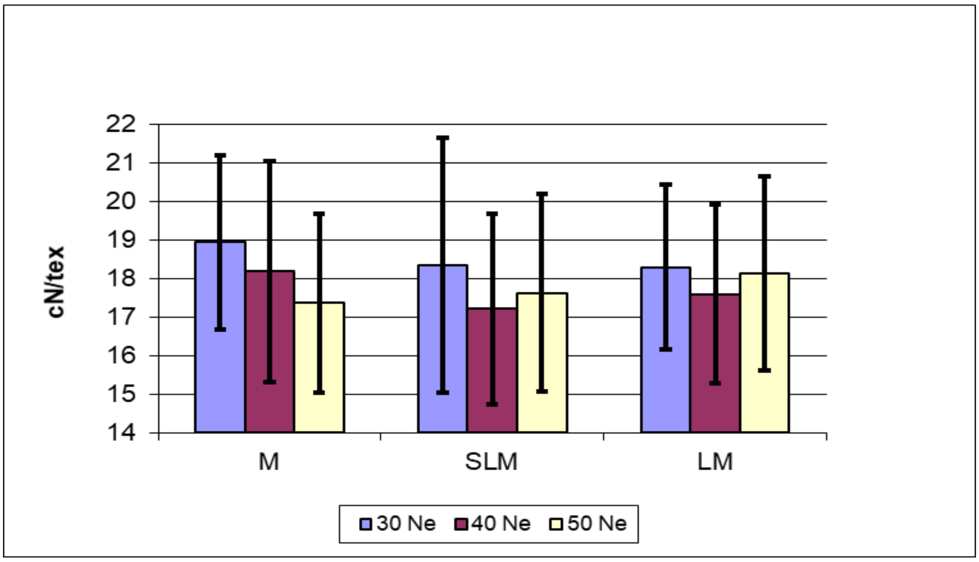

Figure 8. Strength results for ring-spun carded yarns

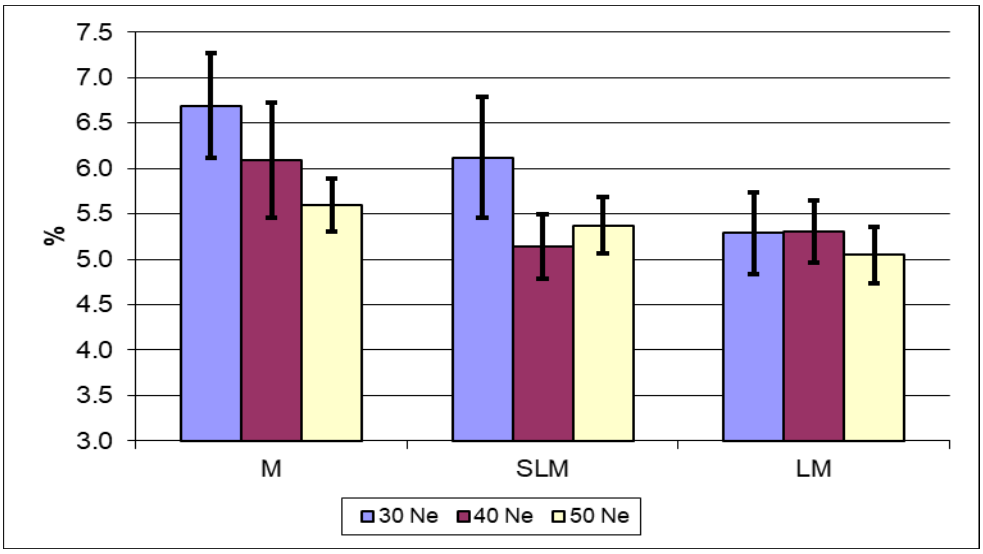

Figure 9. Elongation results for ring-spun carded yarns

Ring-spun combed

The evenness and the imperfection results are shown in Figures 10 - 13. The results also show that the variations in the yarn results were not significant. The strength and elongation results are shown in Figures 14 - 15. Similarly, the variations in yarn strength and elongation were also not significant.

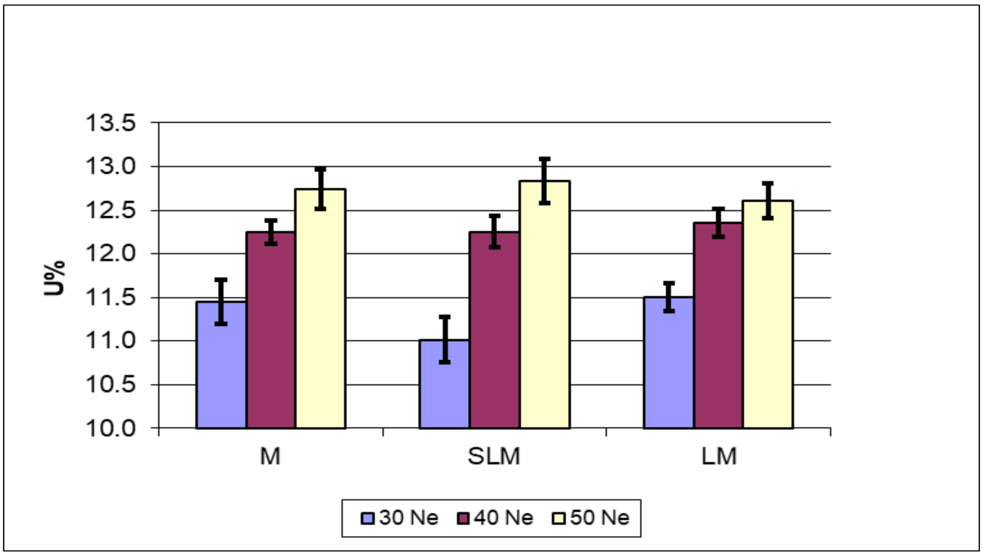

Figure 10. Evenness results for ring-spun combed yarns

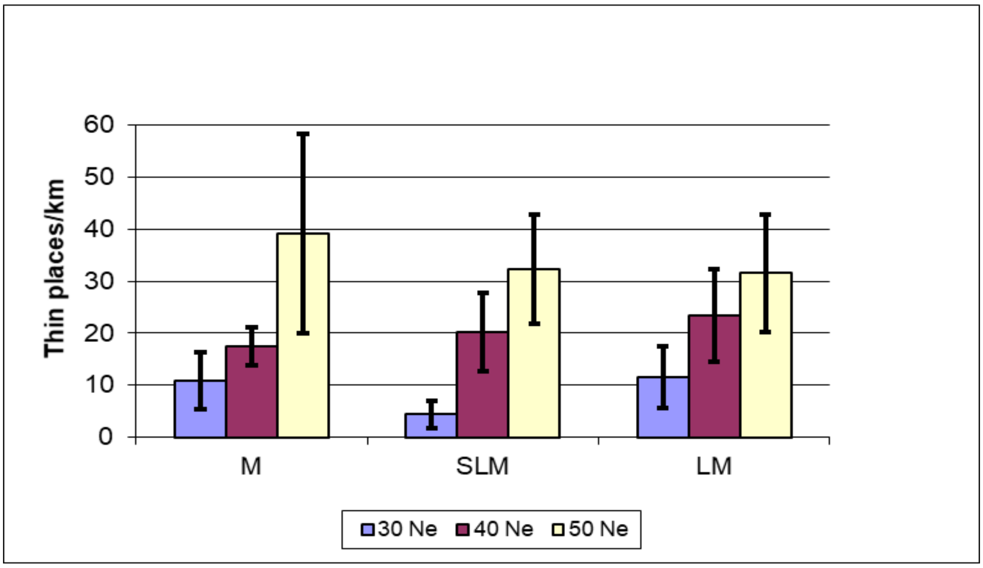

Figure 11. Thin places for ring-spun combed yarns

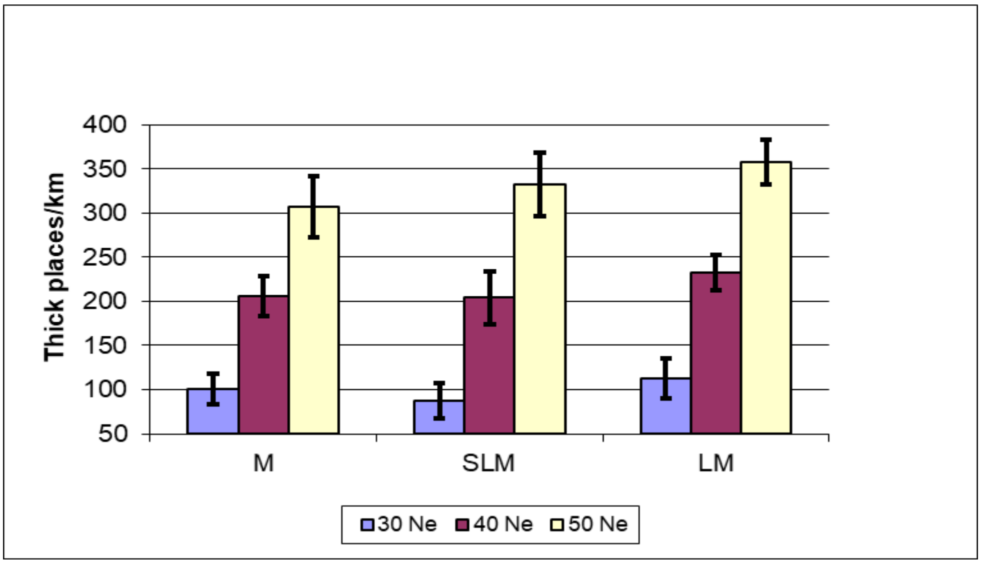

Figure 12. Thick places for ring-spun combed yarns

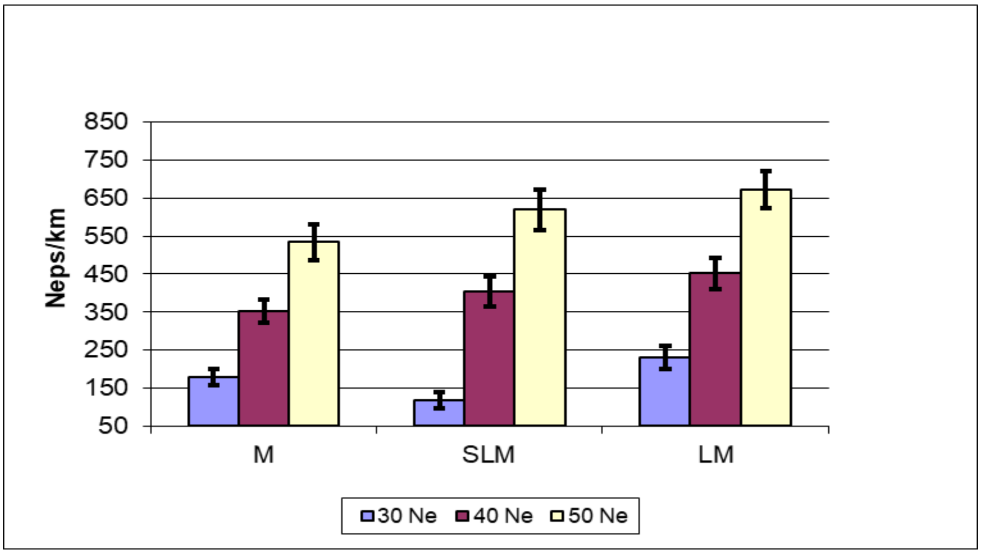

Figure 13. Neps for ring-spun combed yarns

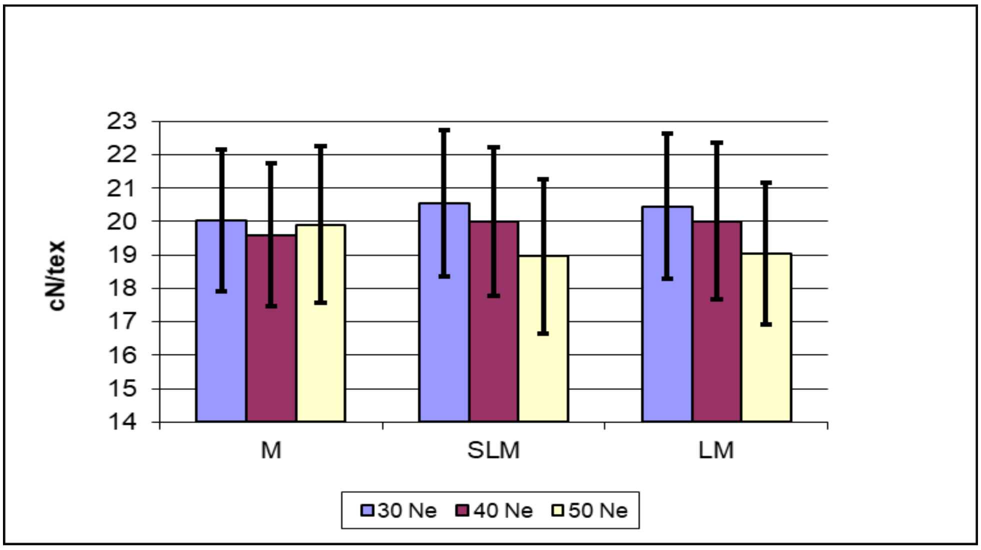

Figure 14. Strength results for ring-spun combed yarns

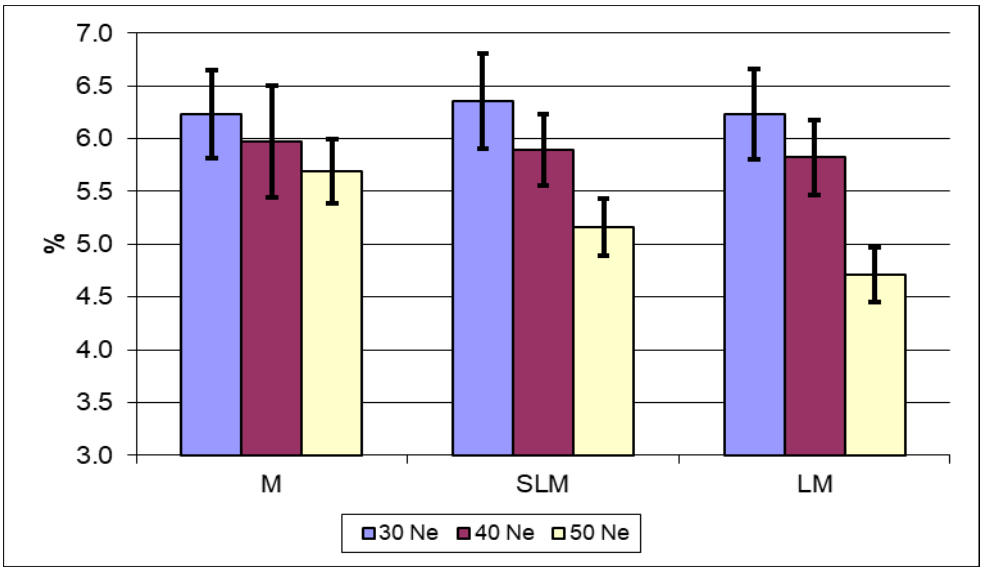

Figure 15. Elongation results for ring-spun combed yarns

Rotor-spun

The evenness and imperfection results are shown in Figures 16 - 19. The results show that although there were variations in the yarn results these variations were not significant. Similarly, there were no significant differences in the strength and elongation results as shown in Figures 20 - 21.

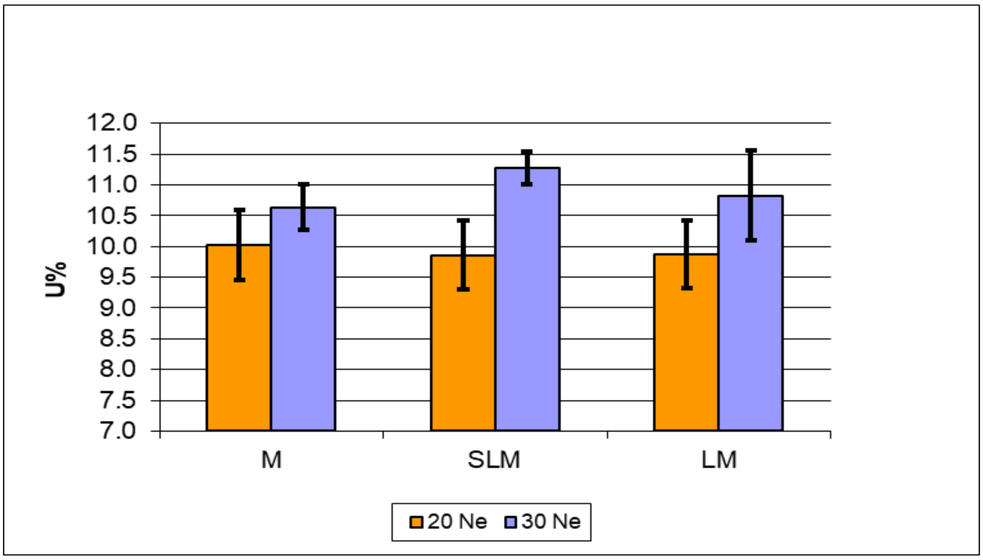

Figure 16. Evenness results for rotor-spun yarns

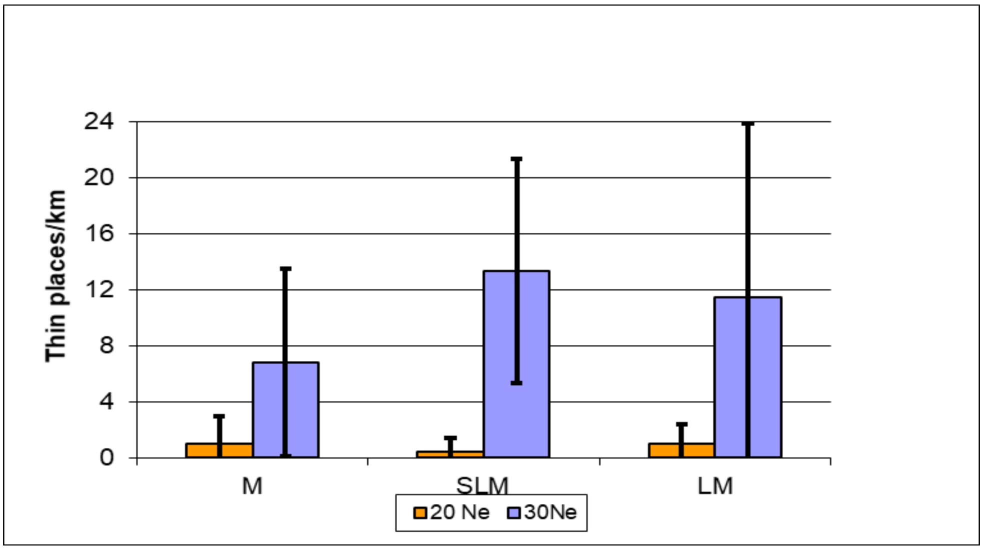

Figure 17. Thin places for rotor-spun yarns

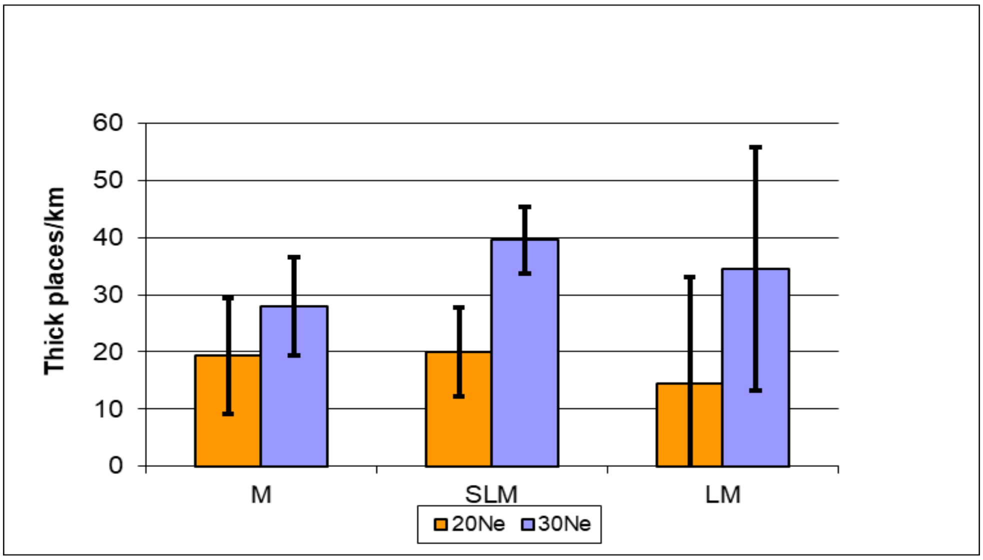

Figure 18. Thick places for rotor-spun yarns

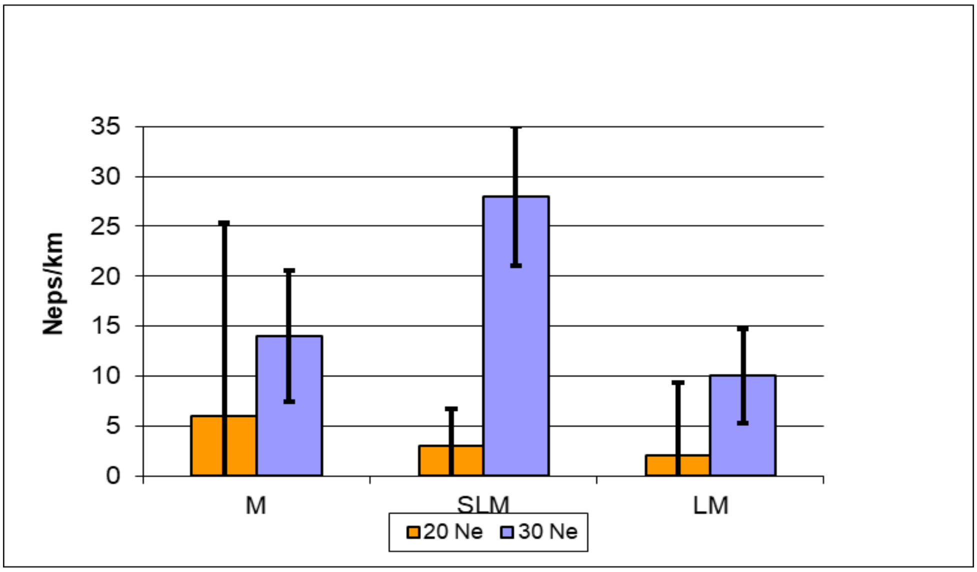

Figure 19. Neps for rotor-spun yarns

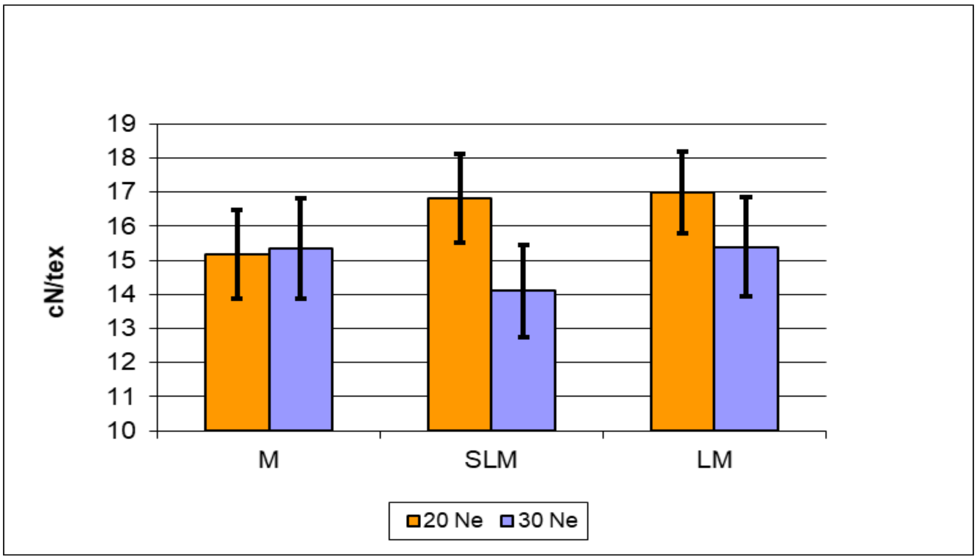

Figure 20. Strength Results for rotor-spun yarns

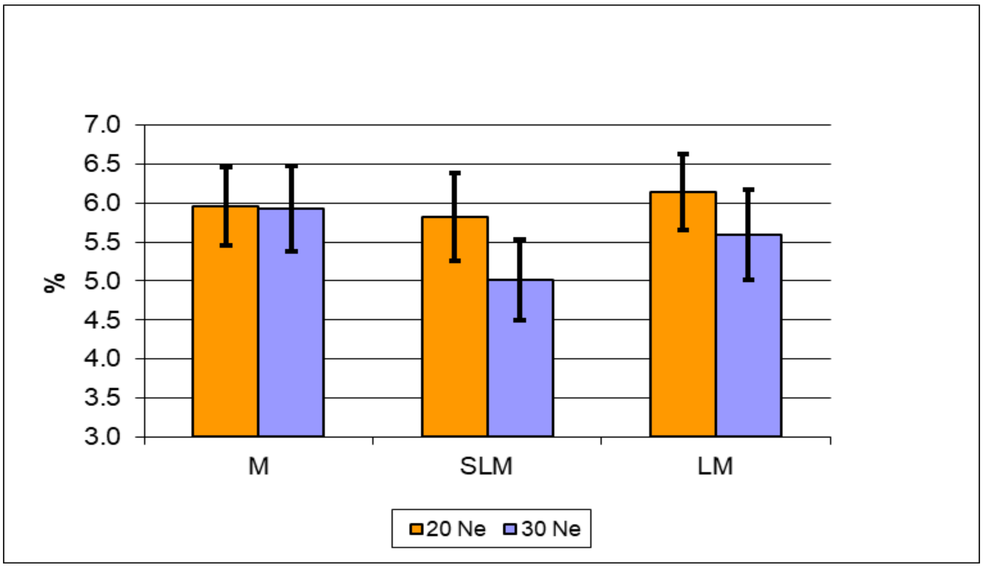

Figure 21. Elongation results for rotor-spun yarns

Processing Performance

Another important measure of cotton lint quality is processing performance. The recording of end breakages in spinning is an important measure of processing performance as it is a good indicator whether production levels and quality standards can be achieved. The processing performance of all carded and comber ring-spun yarns produced was excellent (d15 ends down/1000 spindle hours), with the exception of the carded 50 Ne, although at < 25 breaks per 1000 spindle hours can still be considered average (Lord 2003) - see Table 4. Ends down for the rotor-spun yarns were not formally monitored during the trial but feedback from the operator suggested that end breaks during processing were not an issue.

Table 4. Ends down per 1000 spindle hours per CG and Yarn Count

Yarn Count	M	SLM	LM
Ring-spun carded			
30 Ne	6	7	0
40 Ne	9	4	0
50 Ne	21	22	11
Ring-spun combed			
30 Ne	7	15	0
40 Ne	0	0	0
50 Ne	2	4	2

Conclusions

The results from this trial show that from a yarn manufacturing processing point of view there was little or no difference between cotton with M, SLM and LM color grade, similar trash grade, and HVI properties. Cotton is currently grown in sixty countries worldwide, with around 34% of the cotton produced annually exported for processing and consumption in textile mills (ICAC 2018). Spinners are therefore forced to blend cottons together from a number of countries in order to maintain consistency and remain competitive. The photo below, taken by the author at mill in Vietnam, clearly shows how cotton with big variations in color grade are blended to produce a uniform blend. Spinners are more concerned with the uniformity in color and HVI parameters such as length, strength and micronaire of their blend than with the actual color of the individual bales.

Figure 22. Bale laydown in spinning mill in Vietnam

This uniformity is important for yarns which will be converted into fabric and then dyed into required colors. Even then there are a number of pre - treatments that are conducted prior to dyeing, with scouring and bleaching the most common. Scouring is performed to remove cotton wax and other impurities with bleaching further removing impurities and providing a uniform white base which assures even dyeing.

Acknowledgements

The author gratefully acknowledges the financial support of the Cotton Research and Development Corporation and CSIRO. He also acknowledges the assistance of Fred Horne and Mark Freijah for processing the fiber through to yarn as well as Susan Miller for testing the samples.

References

Abbot, A. M., E. F. Hequet, G. J. Higgerson, S. R. Lucas, G. R. S. Naylor, M. M. Purmalis and D. P. Thibodeaux (2011). "Performance of the Cottonscan(TM) Instrument for Measuring the Average Fiber Linear Density (Fineness) of Cotton Lint Samples." Textile Research Journal 81(1): 94-100.

Anon (2000). Revision of Cotton Classification Procedures for Determining Upland Color Grade. Federal Register. Washington, DC., United States Government Printing Office. 65: 36597-36601.

ASTM (2012a). D5867 Standard Test Methods for Measurement of Physical Properties of Raw Cotton by Cotton Classification Instruments. West Conshohocken, PA, ASTM International: 5.

ASTM (2012b). D1684 Standard Practice for Lighting Cotton Classing Rooms for Color Grading. West Conshohocken, PA, ASTM International: 4.

ASTM (2012c). D5866 Standard Test Method for Neps in Cotton Fibers. West Conshohocken, PA, ASTM International: 3.

ASTM (2014). D1425 Standard Test Method for Evenness of Textile Strands Using Capacitance Testing Equipment. West Conshohocken, PA, ASTM International: 5.

ASTM (2015a). D1776 Standard Practice for Conditioning and Textile Testing West Conshohocken, PA, ASTM International: 5.

ASTM (2015b). D2256 Standard Test Method for Tensile Properties of Yarns by the Single-Strand Method. West Conshohocken, PA, ASTM International: 13.

ASTM (2016). D1423 Standard Test Method for Twist in Yarns by Direct-Counting. West Conshohocken, PA, ASTM International: 7.

ASTM (2018). D1907 Standard Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method. West Conshohocken, PA, ASTM International: 9.

Chakraborty, K. and M. D. Ethridge (1999). Cotton Quality Price Differentials from Textile Mills Perspective: An Update. Beltwide Cotton Conference. Orlando, FL: 256-259.

Chakraborty, K., M. D. Ethridge and S. Misra (2000). How Different Quality Attributes Contribute to the Price of Cotton in Texas and Oklahoma? Beltwide Cotton Conference. San Antonio, TX: 374-376.

Ethridge, M. D., S. Swink and K. Chakraborty (2000). Cotton Quality Price Differentials from Textile Mills Perspective: An Update. Beltwide Cotton Conference. San Antonio, TX: 382-385.

ICAC (2018). Cotton: World Statistics. Washington DC, USA, International Cotton Advisory Committee: 293.

Klein, W. (2014a). Blowroom & Carding. The Rieter Manual of Spinning. Wintherthur, Switzerland, Rieter Machine Works Ltd. 2: 88.

Klein, W. (2014b). Spinning Preparation. The Rieter Manual of Spinning. Wintherthur, Switzerland, Riter Machine Works Ltd. 3: 80.

Lord, E. (1956). "Airflow Through Plugs of Textile Fibres Part 2." Journal of the Textile Institute 47(1): T16-T47.

Lord, E. and S. A. Heap (1988). "The Origin and Assessment of Cotton Fibre Maturity." International Institute for Cotton: 36.

Lord, P. R. (2003). Quality and Quality Control. Handbook of Yarn Production - Technology, Science and Economics. P. R. Lord. Cambridge England, Woodhead Publishing Limited: 276-300.

McVeigh, M. (2017). The Impact of Colour Discounts to the Australian Cotton Industry. Sydney, NSW, Nuffield Australia: 50.

Reid, P. (2002). "Sicot 80." Plant Varieties Journal 15(3): 24.

Stiller, W., M. P. Bange and D. Kelly (2008). Weather Conditions 2007-2008. CSD Variety Trial Results Wee Waa, NSW, Cotton Seed Distributors Ltd.: 84-85.

van der Sluijs, M. H. J. and S. Gordon (2005). "Less Gin Cleaning for Better Fibre Quality." Australian Cotton Grower 26(1): 29-36.

van der Sluijs, M. H. J. and L. Hunter (2016). "Review on the Formation, Causes, Measurement, Implications and Reduction of Neps during Cotton Processing,." Textile Progress 48(4): 221-323.

van der Sluijs, M. H. J. and P. D. Johnson (2011). Determination of the Perceptions and Needs of Mills that Purchase and Process Australian Cotton. Geelong, CSIRO: 128.

van Doorn, D. W. (1986). Modern Ginning and True Cotton Quality. International Cotton Conference. Bremen, Germany: 4.