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TEXTILE TECHNOLOGY

Miniature Spinning: An Improved Cotton Research Tool

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ABSTRACT

Cotton is a natural fiber and is highly variable. Researchers need to evaluate cotton fiber properties to aid in the development of improved varieties and to ensure that changes in agronomic practices do not harm fiber quality or processing propensity. There is a need for fiber quality evaluation beyond laboratory testing which has primarily been designed to assign a value to cotton for trade purposes. The amount of material available to researchers for evaluation is often limited. It is not possible to spin these small samples using conventional processing techniques and machinery. This limitation has led to the development of miniature-scale spinning systems. The objective of this study was to review previously developed miniature processing systems and to introduce an improved system that addresses the weaknesses of previous systems. Commercially available equipment was modified to develop a new miniature spinning system. The newly developed miniature scale processing system was used to convert fiber into quality ring spun yarn. Data were collected to verify the performance of the new system. Depending on the fiber quality, different yarn qualities were produced. The newly developed miniature spinning system processed small cotton samples more efficiently and produced better quality yarn than previous miniature-scale systems.

Cotton is a natural and highly variable fiber. Cotton fiber properties are routinely measured for trading and quality control purposes (Fassihi and Hunter, 2015). Cotton quality is determined by various properties such as maturity, fineness, micronaire, length, strength, etc. These properties vary according to environmental conditions and genetic traits. Breeders are constantly working on improving cotton fiber quality while other researchers are working on improvements to production practices and processes. Research samples need to be evaluated beyond routine fiber testing with instruments such as the High Volume Instrument (HVI™) which measures fiber properties such as length, micronaire, strength, etc., and the Advanced Fiber Information System (AFIS) which measures fineness, maturity, length, short fiber content, neps, and trash. The amount of material available to researchers for evaluation is often limited to between tens and hundreds of grams. It is not possible to spin these small sample sizes using conventional processing techniques and machinery. This limitation led to the development of miniature-scale spinning systems. Since 1920, an assortment of miniature spinning techniques and systems has been developed around the world (Simmons, 1967). Recently, a new miniature spinning system was developed to process small cotton samples more efficiently and to produce better quality yarn than what had been previously achieved.

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A review on miniature spinning

The first small-scale spinning tests were developed in England by W. L. Balls and his associates in the 1920s (Landstreet et al., 1959) and then modified to evaluate cotton varieties and new strains in breeding programs under test in India, Egypt, and at the Shirley Institute in Manchester, UK. All three sites had different test protocols with different amounts of materials utilized (kilograms). Balls and his associates were satisfied that the result of their particular test procedure was representative of the combined effect of all measured and unmeasured fiber properties (Price, 2004). However, cotton breeders were aware that the small-scale spinning test could be more valuable if the required quantity could be reduced, such that the product of one or two cotton plants could be characterized (Price, 2004).

In 1956, the Shirley Institute announced the development and manufacture of a miniature spinning system to test small amounts of cotton more efficiently and in less time compared to processing large samples with industrial scale machinery (Platt Brothers, 1964). Shirley miniature spinning consisted of a small card, draw frame and ring spinning frame. The Platt Brothers (1964) explained the procedure of the Shirley miniature spinning plant: A sample of 42 grams was weighed, if the sample had high trash content, the weight of the sample was increased by 3 grams. The Shirley miniature spinning plant did not have an opener; therefore, no pre-card cleaning was possible. The manufacturer recommendation was to card the sample twice. For feeding the card, laps had to be made by hand. The weighed sample was opened by hand and spread evenly over 50.8 cm (20 inches) of the feed apron of the card. The sample was passed through the card, and the doffed web was allowed to build up into fleece on the collecting drum. After carding, the fleece was transferred to the draw frame and drawn three times. Unlike full-scale spinning, the Shirley spinning system did not include the intermediate step of producing a twisted roving between drawing and ring spinning. The finisher sliver was spun directly into yarn using a high draft spinning frame.

In the United States, the Agricultural Marketing Service (AMS) developed both carded and combed cotton yarn spinning tests which used approximately 2.3 – 4.5 kg (5-10 pounds) of cotton fiber. Conventional equipment and testing procedures were used (Landstreet et al., 1959). By 1959, the sample size was reduced to one pound by introducing a miniature opener/cleaner to prepare a sample for processing. Landstreet et al. (1959) compared the yarn strength of one-pound cotton samples from Clemson and College Station. They found that the one-pound test was slow, inefficient, and expensive as well as requiring too large of a sample for early screening work. Therefore, they developed a miniature test which used only one-half pound of cotton. From their experiment, they found that a half pound of cotton could be processed efficiently and was also the smallest reliable sample that could be easily obtained.

In 1962, the Cotton Quality Investigations Laboratory at Knoxville, Tennessee created a miniature test which resembled the Shirley technique but had greatly increased capacity. This system used only 50 grams of cotton. New methods and machinery were developed to process these small samples efficiently including a custom opener, modified granular card (Miller and Brown, 1959) and small-scale draw frame. They found that the data obtained was consistent with that obtained in the half pound test. They also reported that the 50 gram spinning test utilized the minimum number of machines required to produce quality yarn and took less time to spin a given number of samples by using the granular metallic card, modified drawing frame, and direct sliver to yarn spinning.

Landstreet et al. (1962) explained the procedures for the 50 gram test. The 50 grams of sample was weighed and placed in a numbered bin until the time for processing. To open and clean the very small sample of lint cotton, a special machine, known as a miniature opener was designed. The samples were opened by one pass through the opener. The open lint was made into laps by hand and carded on a modified full-scale granular card. The card was modified by replacing half of the revolving flat strips with aluminum oxide granular card plates. The aluminum oxide carding surface was fixed and rigid and carded without loading thereby reducing card loss. The front of the card was modified by replacing the calendar rolls and coiler with a collection drum to collect fleece instead of sliver.

The laps that were fed to the card were made on trays 50 cm long by 20.5 cm wide. The carded web was collected on the drum (1500 mm circumference and 185 mm width) in the front and removed in the form of laps. These drums were used because they gave a fixed lap length, making it easy to handle the narrow card web, and they produced a well-blended sample through many doublings (Landstreet et al., 1962). The lap was placed on a long tray and drawn three times. The first drawing was collected on a drum in lap form and the second drawing in sliver form 3.2 ktex (45 gr/yd), and a third drawing was done on a modified conventional frame and collected as sliver 3 ktex (42 gr/yd). In the modified draw frame, the calendar rolls and trumpet were moved forward 28 cm to accommodate the collector drum. The draw frame was fitted with a gearbox to allow for a wide range of draft and draft distribution between all rollers. The gearing was designed to allow for rapid roll setting changes. The frame was provided with a high range variable speed drive, dual twist gearing, vacuum scavenging, ball bearing bottom rollers and combination spring, and dead weight top rolls. The finisher drawing sliver was spun directly into yarn on a high draft ring spinning frame. The drafting system was designed and built at the Knoxville laboratory (Landstreet et al., 1962).

Recently, the Commonwealth Scientific and Industrial Research Organization (CSIRO) developed a hybrid miniature spinning system (Van Der Sluijs et al., 2009). This system is a combination of components from the Shirley miniature spinning plant and industrial scale spinning machinery. This system uses the miniature system for carding and a single drawing passage, while industrial-scale machinery is employed for a second draw passage, the creation of roving and ring spinning. This hybrid system uses 170 grams of sample and cards using the Shirley miniature card. Carded cotton was drawn into four separate slivers using the Shirley miniature draw frame. Four slivers were combined into one sliver through a second draw passage using a full-scale draw frame. Drawn sliver was converted into twisted roving on a full-scale roving machine, and yarn was produced using a full-scale ring spinning. More recently, CSIRO has integrated part of a commercially available small-scale textile processing system (Tianjin Jiacheng Mechatronic Equipment Co., China) to replace the Shirley miniature card and draw frame (Long, 2016).

Advantages of different miniature spinning systems.

The miniature spinning systems are a fast process compared to processing on an industrial scale, and they require smaller amounts of fiber. The Shirley miniature spinning system reduced the production time and cost, as it did not include the intermediate step of producing a roving between drawing and spinning. The AMS spinning system and 50 gram spinning system include an opener/blender which makes it easy to open and blend the samples. Two samples could be carded at the same time by utilizing more width of the AMS card. The 50 gram spinning system used a smaller amount of sample compared to the AMS spinning system, though the data obtained was consistent with that obtained in the half pound test. The 50 gram spinning system utilized the minimum number of machines required to produce quality yarn and took less time to spin a given number of samples. Yarn was spun directly from the sliver which reduces the processing time. The 50-gram spinning system used the granular card that reduced the waste instead of revolving flat strips. In the CSIRO spinning system, the yarn was spun using an industrial spinning system; hence the speed of spinning was high (12,000 rpm).

Disadvantages of different miniature spinning systems.

The Shirley miniature spinning system did not include the opener; hence, no opening or pre-card cleaning was possible, therefore; samples had to be carded twice. Yarn spun cotton with this system contained more neps than those spun on conventional machinery using the same cotton (Platt Brothers, 1964). In AMS and 50 gram spinning systems, the opener/blender did not form a lap; laps were made by hand. In the AMS spinning system, the processing time was increased due to the roving process. In the 50 gram and Shirley spinning systems, samples were drawn three times which increased the drawing processing time compared to AMS and CSIRO spinning systems (two drawing only). The CSIRO spinning system did not include the opener/blender; yarns produced from this system were less even (Van Der Sluijs et al., 2009).

Newly developed miniature spinning system

To process small amounts of cotton samples more efficiently and to produce better quality yarn, a new miniature spinning system was developed using ideas borrowed from the previous iterations of miniature-scale processing. The newly developed miniature system presented in this work consists of an opener/blender (SpinLab, Knoxville, TN), a modified Saco Lowell Model 100 carding machine (Easley, SC), a modified Saco Lowell DF11A drawing machine, and SDL Atlas miniature ring spinning frame (Rock Hill, SC).

The opener/blender is a SpinLab Model 338 is designed to open and blend fibers. The opener uses a splined feed roller operating at 4.5 rpm to deliver cotton to a sawtooth opening cylinder operating at 940 rpm. Fiber is pneumatically doffed from the opening cylinder and collected into an air-laid batt in the collection chamber. Multiple passes through the opener/blender ensure uniform blending of the cotton sample while imparting minimal damage. The card used in this process is a Saco Lowell Model 100 with revolving flats. Narrow feed trays (203 mm in width) are used to feed the batt produced by the opener/blender into the card; similar to the Knoxville 50-gram system (Figure 1). The front of the card has been modified to remove the web condenser and sliver coiler, which has been replaced by drums to collect the carded web, as in the AMS system (Figure 2). The collection drums are 215 mm wide with a 1500 mm circumference and contain four rows of perforations, every 90 degrees around the surface of the drum, to allow suction to adhere the card web to the drum initially. The modified draw frame employed in this system, shown in Figure 3, utilizes the drawbox from a Saco Lowell DF11A four-roller draw frame.

The drawbox was removed from the original draw frame. The carded web and/or sliver are fed into the draw frame via a metal feed tray. The crush roll was modified to allow for significantly slower processing rates than commercial operation by removing the corrugations on the original. A variable frequency drive is used to power the draw frame to allow processing speeds to be easily changed. Three trumpets with different size openings are used for first (4.1 mm), second (3.3 mm), and third (2.8 mm) drawing. The first drawing pass converts the carded web into sliver which is then subjected to two additional drawing passages with six doublings used for each passage. The draw frame has been equipped with a revolution counter to allow the length of processed material to be calculated. A ring spinning frame from the Shirley miniature processing plant is used with some modifications. Unlike the Shirley system, slivers are not delivered via a drum; individual slivers are fed to each spinning position. The spinning frame consists of eight spindles with a 38mm ring and spindle speed of 8800 rpm. The Shirley spinning frame has three drafting zones, as opposed to a typical ring spinning frame having only two zones (Figure 4). The Shirley spinning frame has a maximum draft of 402.4 (Platt, 1964) compared to a typical modern ring spinning frame with a maximum draft of approximately 85 (Schlafhorst, 2018). The newly developed system deviates from the manufacturer's guidance on draft distribution with relatively high back draft, low draft in the middle zone and highest draft present in the front zone. The relatively high back draft acts as a way of reducing the bulk of the sliver with the middle draft zone acting in the more conventional role of break draft. The back draft is maintained between 3.0 and 3.5 while the middle draft is kept at 1.17 and the balance of the required drafting is accomplished in the front draft zone. The spinning frame can produce up to 100 Ne yarn when using 1.1 ktex (25 gr/yd) sliver. Yarn is directly produced from the finisher sliver, as opposed to roving. Typically, two bobbins of yarn are produced for each sample, allowing the spinning of four samples simultaneously to increase production capacity. The spinning frame was equipped with roll clearers and a pneumafil-type system to reduce fly, and clear stray fiber to both improve yarn quality and reduce ends-downs to further improve production efficiency. The pneumafil-type system shown in Figure 4a as the white plastic tubing below the front roller, compared to the metal nozzles on the commercial system shown in Figure 4b.

Figure 1. Back side of the carding machine with feed tray.

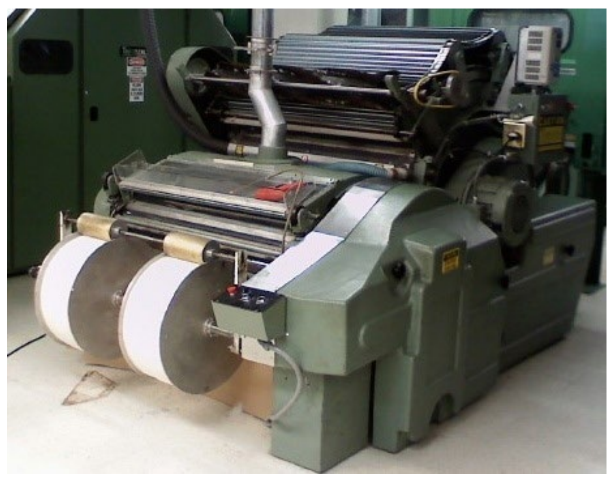


Figure 2. Front side of the carding machine showing collecting drums with carded web.

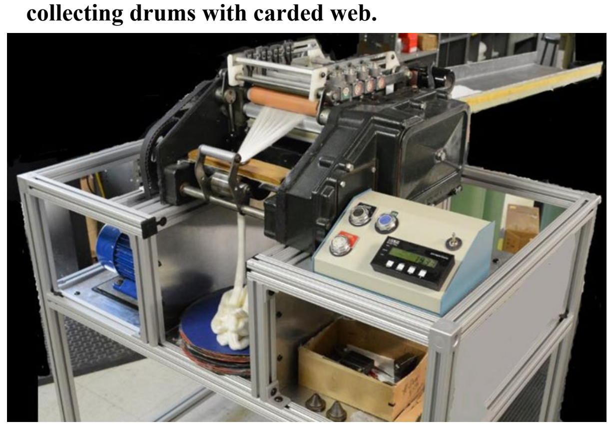
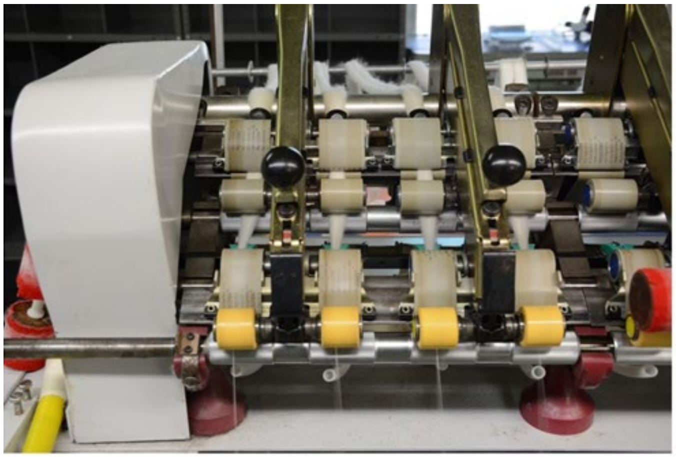
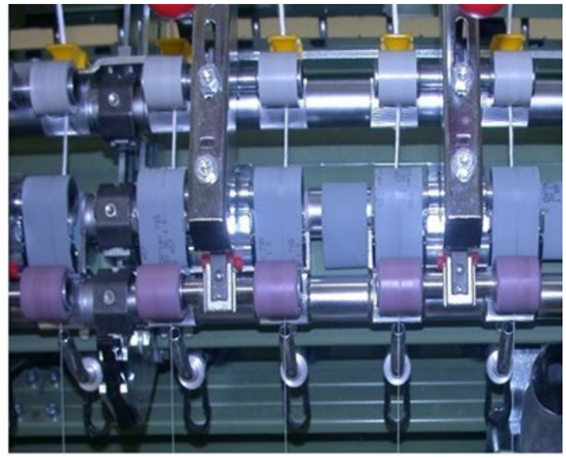


Figure 3. Modified draw frame with metal feed tray at the back and revolution counter at the front.



(a) draft zone miniature spinning frame



(b) draft zone onventional spinning frame

Figure 4. 3 draft zone miniature spinning frame and 2 draft zone conventional spinning frame

Approximately 60 grams of cotton is weighed, opened lightly by hand and fed into the opener/ blender. The sample passes through the feed and opening rollers and is pneumatically collected in a collection chamber as a batt. The batt is weighed and stored in a labeled bin before carding. A disposable sample is fed before test samples to load the revolving flats. On average, it takes about 50 seconds to card one sample. During carding; neps and trash are removed; also some amount of sample is lost due to this cleaning and removal of undesirable content. Approximately 10% of the sample is lost as waste, hence; in this system, 60 grams of sample is used instead of 50 grams. The revolving flats collect trash and neps from the sample, and it needs to be cleaned before carding another sample. The carded web is collected on the collecting drum. The card is run between samples for 1 minute and 40 seconds to clean the revolving flats and provide for consistent card loading. Carded web is weighed to determine weight loss and linear density prior to further processing. The carded fleece is then passed through the draw frame. The main purpose of drawing is to blend and straighten the fibers to make them parallel and increase sliver mass uniformity. The carded material is subjected to three drawing passes to produce 3 ktex (42 gr/yd) sliver. For the first passage the largest trumpet is used, and cotton web is drawn to form 4.2 ktex (60 gr/yd) sliver; for the second passage a smaller trumpet is used, and six doublings are blended and drafted to form one 3.5 ktex (50 gr/yd) sliver, and for the final passage the smallest trumpet is used, and six doublings are drawn to form one 3 ktex (42 gr/yd) sliver. The roll spacings of the draw frame are changed as needed depending on the upper quartile length of the fibers. The yarn (22 and 30 Ne) is produced directly from finisher sliver. Individual slivers are fed to each spinning position. The sliver is drafted in three draft zones, and the yarn is collected on the bobbins. Sliver weights can be altered as needed to allow specific yarn counts up to 100 Ne.

MATERIALS AND METHODS

Samples were collected from a variety of research projects and used for processing trials to verify the performance of the newly developed processing system. Data from 384 samples are presented representing various cultivars and growing locations. The 384 samples were comprised of 240 samples from South Carolina, 72 samples from New Mexico and 72 from Arizona. Cottons were conditioned per ASTM D1776-15 for fiber quality analysis and testing. The fiber quality was analyzed using High Volume Instrument (HVI) and Advanced Fiber Information System (AFIS) (Uster Technologies, Knoxville, TN). HVI 1000 was used with five micronaire readings, five color readings, and five length and strength readings per sample and the AFIS Pro with three replications of 5,000 fibers per sample. The newly developed miniature scale processing plant, as previously described, was used to convert the fiber into 20 tex (Ne 30) and 27 tex (Ne 22) ring spun yarns with a 3.8 twist multiple. Samples of carded web and finisher sliver were collected for testing on AFIS Pro. Yarn strength was tested utilizing a Uster Tensorapid 4 (Uster, Switzerland) with 20 breaks per package per ASTM D2256-15. Yarn uniformity was tested at 100m/min for 1 minute per sample on a Uster Tester 4 (Uster, Switzerland) per ASTM D1425-14. Processing detail is provided in figure 5.

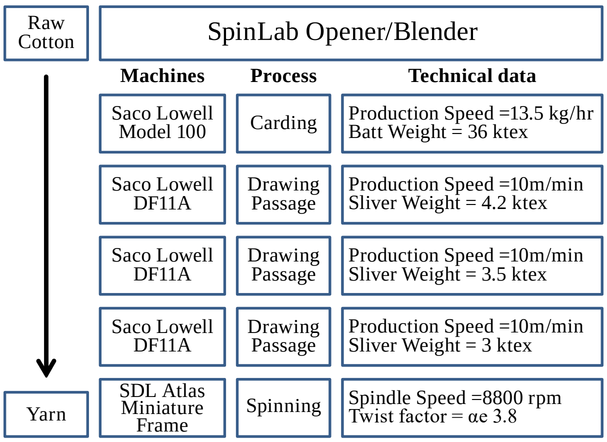


Figure 5. Flowchart of cotton processing in the miniature spinning system.

RESULTS AND DISCUSSIONS

Numerous projects have been processed on the newly developed miniature spinning system. The data presented in this report is intended to show the capabilities of the processing system to handle cottons of a diverse range of quality. The data is selected from projects with various goals, such as investigating agronomic production practices, harvesting methods, and ginning systems. The intention is not to pass judgment on the fiber quality, but to demonstrate that the spinning system handles a diverse range of cotton and that the yarn quality, although not commercial quality, tracks according to the overall quality of the cotton fiber.

The average results of HVI and AFIS fiber testing of raw cotton from Arizona, South Carolina, and New Mexico are listed in Tables 1, 2, and 3 respectively. The micronaire of cottons from all states are in base range (3.5-3.6 or 4.3-4.9 micronaire, National Cotton Council, 2016). The HVI bundle strength value showed that the cotton from Arizona was considered as strong, whereas, the strength of cotton from South Carolina and New Mexico were considered as very strong (USDA-AMS, 2001). If cotton fiber is mature, there is less chance of breakage of fiber, hence has longer length and less short fiber content. The AFIS result showed that the cotton fibers from South Carolina have higher value for maturity (ranged from 0.91 to 1.05) and fineness (ranged from 155 to 210 mtex) than the cottons from the other two states; hence the fiber length of cotton from South Carolina was longer with a lesser amount of short fiber content, and neps count compared to other two states. The range of all the fiber properties was higher for South Carolina cotton than the other two states; this is due to the larger number of samples from South Carolina than the other states. The range of cotton fiber length from New Mexico was higher than other two states. The upper half mean length (UHML) of cotton from New Mexico ranging from 25.9 to 35.8 mm whereas; the fiber length of cotton from South Carolina ranged from 25.9 to 32.3 mm, and from Arizona ranged from 27.4 to 29.5 mm. Overall, these samples represent a broad cross section of US cotton quality.

Changes in AFIS fiber properties during processing of the cottons in three different states are shown in Tables 4, 5, and 6. There was a slight decrease in Upper Quartile length (UQL) and fiber length after carding, as carding is an aggressive process; not only are short fibers removed, but also some fibers can break during this process. The data for short fiber content also showed similar results. The percentage of short fiber content increased after carding. After drawing, UQL and mean fiber length slightly increased; this might be due to the removal of crimp. For all cotton samples, neps count reduced drastically after carding. During carding, trash and neps are removed along with immature and undesirable fiber. Neps count also reduced after drawing, but the reduction was not as high as after carding. Fineness and maturity ratio slightly decreased from raw to card and increased from card to sliver, except in South Carolina cotton samples (Table 5). After drawing, the orientation of the fibers is changed, fibers are more parallel to each other, the hooked ends are straightened, and crimp is removed. In AFIS, maturity ratio and fineness are estimated by analyzing the light refraction pattern obtained from different shapes of an individual fiber. The straighter fibers and fibers with crimp will not refract the light in the same way; hence we assumed that the fiber with crimp has a lower maturity ratio compared to the fiber without crimp (Shahriar et al., 2013).

Table 1. HVI and AFIS fiber properties of cottons from Arizona

Raw cotton; 72 samples, unknown varieties					
HVI			AFIS		
Fiber properties	Average	Range	Fiber properties	Average	Range
Micronaire	4.4	3.8-4.9	UQL (mm)	30.48	29.0-31.5
UHML (mm)	28.45	27.4-29.5	Lw (mm)	25.15	23.9-26.2
UI (%)	82.3	81.2 -83.2	SFCw (%)	8.64	6.6-10.9
Strength (g/tex)	29	27.4-31.7	Neps (cnt/gm)	243.75	171-360
Elongation (%)	7.9	7.4-8.3	Fineness (mTex)	183.89	167-198
Rd	80	78-81	Maturity Ratio	0.97	0.89-1.02
+b	9.6	8.8-10.2			

Table 2. HVI and AFIS fiber properties of cottons from South Carolina

Raw cotton: 240 samples, 20 varieties					
HVI			AFIS		
Fiber properties	Average	Range	Fiber properties	Average	Range
Micronaire	4.8	3.9-5.6	UQL (mm)	31.24	26.4-35.1
UHML (mm)	29.72	25.9-32.3	Lw (mm)	26.67	22.6-30.0
UI (%)	83.8	80.7-86.4	SFCw (%)	4.82	2.5-9.7
Strength (g/tex)	33	28.0-37.9	Neps (cnt/gm)	129.43	58-315
Elongation (%)	8.2	6.7-10.8	Fineness (mTex)	184.22	155-210
Rd	80	73-83	Maturity Ratio	0.98	0.91-1.05
+b	7.3	5.3-9.9			

Table 3. HVI and AFIS fiber properties of cottons from New Mexico

Raw cotton: 72 samples, 3 varieties					
HVI			AFIS		
Fiber properties	Average	Range	Fiber properties	Average	Range
Micronaire	4.3	3.6-4.9	UQL (mm)	32.26	27.2-38.9
UHML (mm)	30.48	25.9-35.8	Lw (mm)	26.42	21.6-32.3
UI (%)	82.4	78.4-86.7	SFCw (%)	8.59	3.6-15.8
Strength (g/tex)	32	24.8-41.1	Neps (cnt/gm)	233.28	127-342
Elongation (%)	8	6.4-9.9	Fineness (mTex)	164.9	139-185
Rd	79	69-84	Maturity Ratio	0.94	0.86-1.02
+ b	8.2	6.3-10.9			

Table 4. Change in AFIS fiber properties during processing in cotton from Arizona

Fiber properties	Raw cotton average	Carded cotton average	% Change from raw to card	Finisher sliver Average	% Change from card to drawing
UQL (mm)	1.19	1.16	-2.52	1.22	5.17
Lw (mm)	0.99	0.94	-5.05	0.97	3.19
SFCw (%)	8.64	11.60	34.26	10.96	-5.52
Neps (cnt/gm)	243.75	97.17	-60.14	74.72	-23.10
Fineness (mTex)	183.89	183.78	-0.06	189.49	3.11
Maturity Ratio	0.97	0.96	-1.03	1.00	4.17

Table 5. Change in AFIS fiber properties during processing in cotton from South Carolina

Fiber properties	Raw cotton average	Carded cotton average	% Change from raw to card	Finisher sliver Average	% Change from card to drawing
UQL (mm)	1.23	1.22	-0.81	1.25	2.46
Lw (mm)	1.05	1.03	-1.90	1.05	1.94
SFCw (%)	4.82	5.99	24.27	5.91	-1.33
Neps (cnt/gm)	129.43	43.99	-66.01	23.41	-46.78
Fineness (mTex)	184.22	192.20	4.33	202.05	5.12
Maturity Ratio	0.98	1.01	3.06	1.05	3.96

Table 6. Change in AFIS fiber properties during processing in cotton from New Mexico

Fiber properties	Raw cotton average	Carded cotton average	% Change from raw to card	Finisher sliver Average	% Change from card to drawing
UQL (mm)	1.27	1.22	-3.94	1.27	4.10
Lw (mm)	1.04	0.97	-6.73	1.01	4.12
SFCw (%)	8.58	12.50	45.69	11.39	-8.88
Neps (cnt/gm)	233.28	130.35	-44.12	98.51	-24.43
Fineness (mTex)	164.89	159.06	-3.54	169.11	6.32
Maturity Ratio	0.94	0.90	-4.26	0.95	5.56

The average results of yarn quality for three different states are listed in Tables 7, 8 and 9. AFIS showed that the samples from Arizona and New Mexico tended to have more short fiber content and lower maturity ratio than the cottons from South Carolina. Yarn from South Carolina had less thin places (-50%), thick places (+50%), and low CVm. New Mexico cotton had fewer neps (ranged from 32 to 786/km) compared to the other two states. The range of thin places for cotton yarn from New Mexico was higher compared to other two states. Thin places of cotton yarn for New Mexico ranged from 4 to 3374/km, whereas, thin places for cotton yarn for Arizona ranged from 434 to 3552/km and for South Carolina ranging from 59 to 3547/km. Cotton fibers from New Mexico were finer (Table 3), hence, more fibers in the cross-section. Therefore, yarn tenacity of New Mexico cotton was higher compared to yarn tenacity of the other two states. Fiber qualities were better for cotton from South Carolina, and produced better yarn quality. The result confirmed that the yarn quality could be predicted from the fiber properties of raw cotton. Cotton with different fiber qualities was processed through the newly developed miniature system, and the yarn was produced.

The average card waste percentages of cottons from all states are listed in Table 10. The data showed that the raw cottons from Arizona contained more neps than the other two states; hence a greater percentage of material was removed as waste during carding.

Table 7. Yarn data for cotton from Arizona

Yarn properties	Average	Range
CVm (%)	27.9	22.52-32.11
Thin 50%/km	1994	434-3552
Thick 50%/km	2390	1161-3433
Neps 200%/km	737	210-1353
Tenacity (cN/tex)[z]	12.2	8.94-14.36
Elongation (%)[z]	6.25	5.26-7.43
Count Strength Product (CSP)[y]	1132	894-1538

[z] Single end

[y] Skein

Table 8. Yarn data for cotton from South Carolina

Yarn properties	Average	Range
CVm (%)	23.3	17.72-32.41
Thin 50%/km	886	59-3547
Thick 50%/km	1372	306-3255
Neps 200%/km	421	54-1248
Tenacity (cN/tex)[z]	13.8	9.54-18.71
Elongation (%)[z]	6.76	5.12-8.60
Count Strength Product (CSP)[y]	1431	899-1842

[z] Single end

[y] Skein

Table 9. Yarn data for cotton from New Mexico

Yarn properties	Average	Range
CVm (%)	23.9	17.35-31.93
Thin 50%/km	834	4-3374
Thick 50%/km	1391	301-3209
Neps 200%/km	264	32-786
Tenacity (cN/tex)[z]	15.1	9.81-19.91
Elongation (%)[z]	7.3	5.85-8.60
Count Strength Product (CSP)[y]	1162	894.4-1610.25

[z] Single end

[y] Skein

Table 10. Card waste from three different states

State	Arizona	South Carolina	New Mexico
No. of samples	72	240	72
Average card waste (%)	6.94	5.74	5.94
Range	4.23-10.95	0.28-17.33	3.70-8.88

CONCLUSION

The main objective of this work was to focus on the development of a miniature spinning system and to verify the performance of the miniature spinning system. Cotton samples of different qualities were collected from three different states; Arizona, South Carolina, and New Mexico and processed through the newly developed miniature spinning system. Fiber and yarn properties were analyzed using HVI, AFIS, Uster Tensorapid 4 and Uster Tester 4. Data were collected to verify the performance of the new system. HVI and AFIS results showed that fiber quality of cotton from Arizona was lower compared to the cotton quality of other two states, and produced low-quality yarn. Whereas, fiber quality of cotton from New Mexico was lower than the cotton quality from South Carolina, but some of the yarn properties (such as thin places, neps, elongation, and tenacity) were better for New Mexico cotton than for South Carolina cotton. Therefore, to predict yarn quality accurately, relevant information about fiber quality is needed and further investigation is needed to compare the results of the new miniature spinning system with other systems.

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DISCLAIMER

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