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Comparative Analysis of Yarn Properties Produced from Different Varieties of Cotton under Ethiopian Cultivars

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Abstract

Yarn property is dependent on the properties of its constituent and the arrangements of fibers within the yarn, the mass distribution of yarn along its length. This research was focused to analyze the effect of different cotton fiber properties from common varieties grown in Ethiopian on yarn properties. Three types of cotton samples from DP 90, Stam 59A, and Local cotton varieties, were assessed. High Volume Instrument (HVI 1000) was used to characterize the properties of the fibers. Fiber characterization was conducted using HVI instrument followed by yarn production with a laboratory scale China mini mill spinning machine. The correlation between fiber and yarn properties on (Tex 30) count which is commonly produced in Ethiopian textiles was analyzed using Minitab 17 software. The results indicated that yarn spun from the local cotton shows with better yarn properties.

Keywords: DP 90 • Hairiness • Stam 59A • Yarn evenness • Yarn strength

Introduction

Production of quality yarn for textile mills with a minimum cost without harming the environment is the main concern of the textile industries. The process of yarn production can be influenced by several factors such as properties of raw material, level of technology, machinery, and skill of machine operators. The effect of fiber quality on yarn obtained property plays the main role. Predicting yarn properties from fiber parameters has been the main focus for many years. To support the increasing number of textile and garment industries in Ethiopia, constant supply of quality raw materials is a critical concern. This study was undertaken in order to check the suitability of Ethiopian cotton to produce quality ring-spun from samples obtained during 2018-2020 production seasons [1]. The most common and commercially produced variety in Ethiopia, DP 90, the local variety and stam 59A were assessed for their suitability in producing quality ring spun yarn using different testing equipment. The main objective of this work was to characterize the cotton fiber properties growing in the Northern and Eastern parts of Ethiopia towards its suitability in producing quality ring spun yarn. In this work, High-Volume Instrument (HVI) fiber properties were used for the prediction of yarn properties. In other studies, Manual Suter-Webb (SW) Array method has been used to study the correlation between yarn strength, irregularity, and frequency of thick places, thin places, and neps of the yarn produced [2].

There are many types researches conducted to study the relation between fiber properties and their effect on yarn quality considering the cost and quality of yarn. Faulkner specifically clarifies the relationships between ring-spun yarn quality and fiber properties based on HVI and AFIS. On the other hand, Liu assessed the effect of short fiber (<12.7 mm long) on yarn quality. In Ethiopia, the cotton selection and blending for yarn production is done in a traditional process. The mill operators determine the mix ratio of bales based on intuition and personal experience, which results in a high cost of blend and quality giveaway. This work considers three types of cotton varieties grown in Ethiopia [3]. The investigation of the physical properties of each variety was done intensively to study the effect of fiber properties on yarn quality. High-count variation can result in many quality problems including high yarn irregularity, variation in fabric weight, and variation in dye uptake. Yarn strength and fineness are dependent on fiber maturity. High micronaire value cotton exhibited more convolutions than low micronaire counterparts, and longer fibers exhibited higher frictional properties than shorter ones. The presence of convolutions in matured fibers increases the spin ability of the fiber due to an increase in the cohesiveness of fibers.

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Materials and Methods

Sampling and fiber testing

To characterize cotton fiber properties of different cotton varieties for their suitability in the production of quality ring-spun yarn, samples were collected from Northern and Eastern parts of Ethiopia mainly from the Amhara, Benishangul Gumuz, and Afar regional states during 2019 and 2020 production year. Specifically, the samples were collected in the Metema and Quara wored as of Amhara region and Worer and Asosa agricultural research centers. The experimental process covers fiber testing, yarn production, and yarn testing. The main cotton variety DP 90, Stam 59A, and local cotton were considered in this investigation [4]. The samples were conditioned using standard conditioning chambers in Ethiopian Textile and Fashion Technology Institute (EiTEX), Bahir Dar University laboratory, and in the State Key Laboratory of Textiles, Donghua University Shanghai, China. The quality of the three samples DP 90, Stam 59A, and local cotton were selected and analyzed using USTER HVI 1000. The main fiber quality of cotton tested was fiber length, length uniformity, short fiber content, strength, elongation, microniare value, and strength. Tables 1-3 shows the fiber properties of different types of cotton DP 90, local cotton and Stam 59 A. As illustrated in the table Local type cotton has better UHML followed by DP 90 in case of tensile strength Local type cotton has better tensile strength followed by DP 90.

Variable	Count	Mean	SE Mean	StDev	CoefVar	Minimum	Maximum
mic	50	3.92	0.04	0.41	10.41	2.8	4.78
mat	50	0.85	0	0.01	1.31	0.82	0.87
UHML	50	28.62	0.16	1.52	5.3	26.17	32.23
UI	50	83.28	0.27	2.53	3.03	78.1	89.2
Strg	50	28.04	0.25	2.29	8.18	23	35.4
elong.	50	6.37	0.08	0.76	11.93	4.6	8.5

Table 1. Fiber property statistics DP 90.

Variable	Count	Mean	SE Mean	St Dev	Coef Var	Minimum	Maximum
mic	52	3.74	0.06	0.47	12.48	2.8	4.78
mat	52	0.84	0	0.01	1.31	0.82	0.87
UHML	52	30.09	0.19	1.38	4.59	26.48	32.23
UI	52	86.02	0.21	1.482	1.72	82.4	89.2
SF	52	6.51	0.12	0.91	13.89	4.8	9.2
STR	52	29.65	0.4	2.86	9.65	23	36.2
Elon	52	6.89	0.1	0.69	10.02	5	8.5
Sci	52	158.98	2.3	16.6	10.44	128	188

Table 2. Fiber property statistics local cotton.

Variable	Count	Mean	SE	StDev	CoefVar	Minimum	Maximum
mic	52	4.12	0.03	0.18	4.49	3.73	4.49
mat	52	0.86	0	0.01	0.72	0.85	0.87
UHML	52	27.77	0.11	0.79	2.84	26.17	29.23
UI	52	81.53	0.17	1.23	1.51	78.1	83.8
SF	52	11.4	0.26	1.87	16.35	7.6	15.8
STR	52	27.33	0.23	1.64	5.99	24.7	33.7
Elon	52	6.04	0.07	0.52	8.64	4.6	7.3
sci	52	121.29	1.49	10.77	8.88	99	148

Table 3. Fiber property statistics Stam 59 A.

Yarn production

Yarn preparation: After evaluation of the physical characteristics of cotton samples obtained from DP 90, stam 59A and, local varieties, they were manually opened and processed in carding and drawing sections with appropriate machine settings for the different counts (Table 4). The cotton samples from different varieties were processed to form roving of the same hank. Yarn production was conducted on a laboratory-scale using China mini mill spinning machine. To eliminate spinning variations, the roving samples were ring spun into yarns under the same conditions on the same spinning machine with the same parameter [5]. Yarn count (Tex 30) with twist amount 750 turns per meter was produced from three different types of cotton verities and the comparison of the mass variation, thick place; thin place neps, strength, and elongation were assessed. To identify, which variety of cotton produces the best yarn quality, the probability plot of the different yarns produced from different cotton varieties were assessed by using minitab 17 software. Raw material mixing is a process of using different quality parameters and prices of fiber based on the spinning system and end application of yarn to get the required quality of yarn at a minimum cost by appropriate cotton fiber selection and cotton fiber mixing technology [6].

Process parameters in textile unit system (Tex)	Value	Equipment used
Sliver count (Tex)	4921	Micro-blowing and carding combined testing machine model FA158-50H
Drawing sliver count (Tex)	4921	Draw frame: CNST-B01
Roving count (Tex)	421	Roving frame: CNST-C02
Yarn count (Tex)	30	Spinning frame: CNST-X01

Table 4. Experimental process parameters and equipment's used for yarn production, silver count, roving count yarn count and, yarn twist amount.

Yarn properties testing

In this research, parameters yarn count, twist, evenness, yarn tensile strength yarn elongation, and hairiness were tested and analyzed following the international standard test methods shown in Table 5.

Type of test	Lab equipment	Test method
Fiber properties	HVI 1000 test	ASTMD4605-86
Yarn count	The skein method	ASTM D1907-07
yarn twist	Y331N twist tester	GB/T 2543-2011
Yarn strength	YG061-1500 tensile strength tester	ISO 2062:2009
Yarn evenness	CT 3000 evenness tester	ASTM D1425/D1425M

Table 5. International test methods applied to test fiber and yarn properties.

Statistical analysis

Comparative analysis was applied to establish a quantitative relationship between yarn produced from different varieties. The input parameters for the analysis were different cotton varieties with different fiber properties, while the output parameters were the mass variation (CvM) and yarn Tensile strength and yarn hairiness. The analysis was made by using Minitab® 17 statistical software (MINITAB, 2006). Different methods of mathematical analysis can be used to study the relation b/n fiber properties and yarn property namely the Fiber Quality Index (FQI), the Spinning Consistency Index (SCI), the Premium-Discount Index (PDI), and Multiple-Criteria Decision-Making (MCDM) technique had been used to analyze the correlation between fiber properties and yarn properties. The Suter-Webb array technique is also a method of fiber assessment that gives higher estimates of short fiber content than the measurements in HVI and AFIS which can be also used for the analysis of fiber yarn property relationships. The feasibility of utilizing HVI fiber micronaire and strength property data, as a semi-quantitative and fast tool, to compare the yarn tenacity performance can be used for analysis [7].

The importance of linear density of fiber in determining the finest yarn that can be spun before a high amount of irregularity happens has been the main study area. For medium staple cotton, about 80 fibers per cross-section are required in ring-spun yarn and bout 110 fibers in open-end spun yarn. For this research, comparative analysis was used to see the effect of fiber properties on yarn quality using minitab 17 statistical software. Three different types of cotton varieties were mixed at equal proportion and yarn count (Tex 30), medium count yarn was produced for further analysis to see the effect of each fiber property of cotton varieties grown in Ethiopian on yarn quality.

Results and Discussion

Yarn count and twist

To study the effect of fiber properties on ring spun-yarn quality, yarn with a low twist factor was produced and the nominal counts designed to be spun were Tex 30 with an average twist of 750 turns per meter. Yarn count were measured by using hank methods and yarn twist was measured using the untwist-retwist method on the digital twist tester (Y331N Twist tester) using the standard test method [8]. The yarn samples were produced from the main cotton varieties which grow in Ethiopian cultivar (DP 90, stam 59A, and local types of cotton) (Table 6). The yarn samples were coded based on the main cotton varieties in Ethiopian cotton variaities as yarn 1 produced from DP 90, yarn 2 produced from stam 59A and and Yarn 3 produced from local cotton variety.

Sample code		
Yarn1	Yarn2	Yarn3

Yarn1=Yarn produced from Dp 90 type cotton Yarn2=Yarn produced from Stam 59A type cotton Yarn3=Yarn produced from Local type cotton

Table 6. Sample codes of yarn produced from the main cotton varieties in Ethiopian cultivar.

Yarn evenness testing

The comparison of the effect of different cotton types on yarn properties was assessed by using (Tex 30) yarn. The yarn's evenness was tested on the CT 3000 evenness tester. This machine adopts advanced Charge-Coupled Device (CCD) digital imaging technology to test the appearance of the quality of yarns, such as diameter, appearance and outline changes, faults, and hairiness of yarns. The control of this tester to yarn evenness is stronger than the user tester, and the sensitivity to the yarn unevenness is better than the user CV values measured by user evenness tester [9-13]. This equipment uses capacitance to measure the coefficient of variation, no of thick place, number of thin places and neps (Figures 1 and 2). From the graphs, it can be drawn that Yarn spun from local type cotton has a lower Coefficient of variation, number of thick places and, thin places, and neps per gram. From the graphs, it can be drawn that yarn spun from local type cotton has a lower Coefficient of variation, number of thick places and, thin places, and neps per gram (Figure 1).

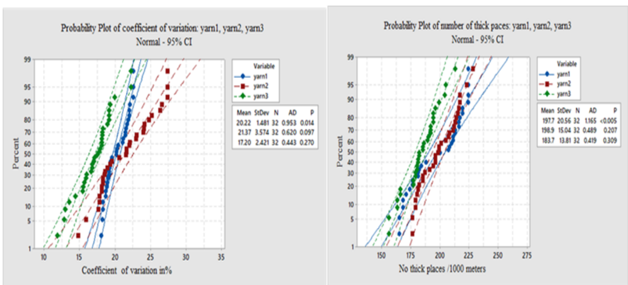

Figure 1. Probability plot of mass variation and number of thick places in 1000 meters of yarn samples spun from three different cotton varieties: Local, Stam59A and DP 90.

Imperfections

The measurement of the number of neps, thick and thin places per 1000 meters of the yarn using a CT 3000 evenness tester was conducted to assess the level of imperfections. This was determined when the yarn passes through the condenser and recorded in terms of the total number of neps, thick places, and thin places per 1000 meters of yarn according to D1425/D1425M test procedure the imperfection value, high amount of thick place, thin place, and neps were more common in sample yarn produced from DP 90 type cotton (Figure 2) [14].

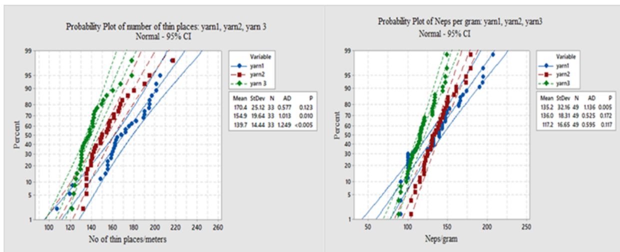

Figure 2. Probability plot of the number of thin places in 1000 meters and Neps/gram of yarn samples spun from three different cotton varieties: Local, stam 59A, and DP 90.

From the comparative analysis, the local cotton type has high tensile strength followed by DP 90. Regarding yarn elongation, DP 90 has high extensibility followed by local cotton and stam 59A (Figure 3). According to D1425/D1425M test procedure the imperfection value, high amount of thick place, thin place, and neps were more common in sample yarn produced from Dp 90 type cotton (Figure 3).

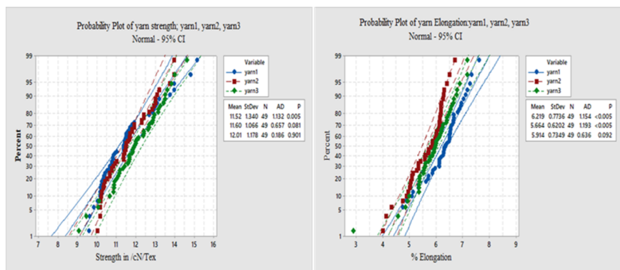

Figure 3. Probability plot of Tensile strength and percentage elongation of yarn samples spun from three different cotton varieties: Local, stam 59A and DP 90.

Yarn strength and elongation testing

The tensile properties of yarn were determined on YG061-1500 yarn tensile tester at room temperature by following ISO 2062:2009 FZ/T01034 test method. In this equipment, the cross-head speed and gauge length was 250 mm/min and 250 mm respectively, and the pre-tension was 5cN. The values of tensile Force (F), elongation at break (ε) were assessed. Yarn produced from stam 59 had better tensile strength and the local cotton variety has a good elongation (Figure 3) [15].

Yarn hairiness testing

YG172A yarn hairiness tester was used to test and analyze the yarn hairiness index. It can test and analyze hairiness length, number and distribution of yarn automatically. Testing speed 100 m/min and the indices of hairiness length 3 mm were considered for this analysis. The number of hairs is relatively high on the yarn produced from DP 90 type cotton (Figure 4).

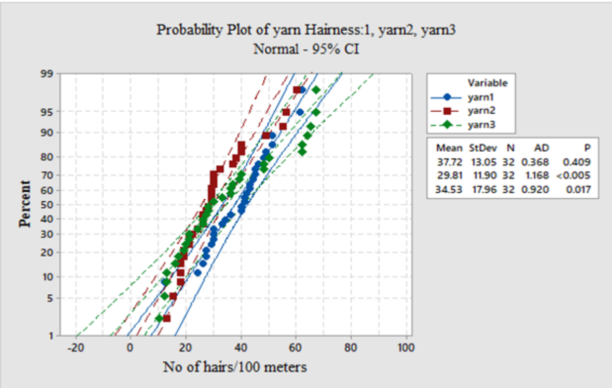

Figure 4. Probability plot of the number of hairs of yarn in100 meters of yarn samples spun from three different cotton varieties: Local, stam 59A and DP 90.

Conclusion

From the yarn produced in different types of cotton samples, the one obtained from local cotton has better property in mass variation, and imperfections but the hairiness effect is less visible on stam 59A type cotton. Regarding the tensile strength, yarn produced from sample Dp 90 has better average tensile strength. The research work give information about the quality and suitability of Ethiopian different cotton varieties to produce quality ring spun-yarn (Tex 30), to show the relation between yarn properties and fiber properties and to the emphasis which variety will give better yarn quality for that specific yarn count which is commonly produced in Ethiopia The results indicated that yarn spun from the local cotton had better mass variation value, lower thin place, thick place, and neps followed by yarn produced from stam 59A. Yarn produced from Local cotton had better tensile strength followed by stam 59A. On the other hand, in terms of elongation yarn produced from DP 90 type cotton showed better results; more hairs were visible on yarn produced from DP 90 type cotton. From the analysis, it can be shown that the local variety of cotton can produce yarn with better yarn properties.

The varieties of cotton fiber used for spinning should be selected based on the intensive test results and its performance on yarn quality. The Ethiopian spinning technology should have to be integrated in to the cotton farming technology to select the best cotton variety which can perform well in spinning. For the future, Ethiopian cotton-based textile industries should select cotton fiber as a raw material based on the variety of cotton and its fiber properties for its appropriate end application.

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