Knit Structure and its Relationship to Dimensional Stability, Appearance Retention, Industrial Stretch, Pilling Resistance and Colorfastness to Crocking

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Abstract
The study examined selected performance attributes of three knit structures in different fiber contents. Several AATCC and ASTM standards were used to compare interlock, jersey and pique knits. Both descriptive and inferential statistics were used to analyse the data. Analysis of variance (ANOVA), t-tests, and descriptive statistics were used to analyse the data. Findings revealed that textiles in different fiber contents and structures did not perform similarly for the selected performance attributes. Possibilities for future extension and relevance of the yielded results was highlighted. Implications of the findings refining and extending the existing knowledge of textile and apparel manufacturers, retailers, and consumers for care, comfort and appearance were highlighted.

Keywords — *knit structure, appearance retention, colorfastness to crocking, dimension stability, pilling resistance, stretch*

I. INTRODUCTION

Textile and apparel consumers value appearance, care and comfort. Today's busy schedule and issues with balancing work and family compel consumers to look for easy wear and care in textiles. Due to increased variety of textile materials in its purest and blended forms has confused consumer to understand specific performance characteristics of textiles used in ready to wear apparel. Consumer goes with the information on the labels as provided by apparel manufacturers and retailers. With plethora of textiles available in the market, consumer needs to understand textile properties better than was necessary with less diversity of fiber contents. The study selected appearance (appearance retention, and pilling resistance), care (dimensional stability and colorfastness), and comfort (stretch) attributes of three knit structures to address the existing gap in the previous literature.

II. LITERATURE REVIEW

Relevant research is presented below to establish foundation for the reported investigation. Previous dimensional stability research focused on the impact of number of launderings [1] – [3], adding cotton to polyester [4], effect of enzyme treatment [5], influence of stitch length [6] – [8], and impact of laundering on weight, thickness and cover [8] [2] – [3], directional stability [8], The results revealed that number of washing impacted dimensional stability [1] – [2]. For t-shirts study the changes were significant for front length and neck opening [3]. Cotton polyester blend had higher dimensional stability on both directions [4]. Adding enzymes increased shrinkage of weft knits [4]. Shrinkage was less for the shorter stich length than the longer stitch length [5] – [6]. Laundering increased cover, thickness and weight [8]. Additionally, knits were found to be more stable in lengthwise than crosswise direction [8]. Both cotton and poly cotton blends shrank after laundering [3]. However, except for neck opening, cotton shrank more than the blend [3]. It could be function of curvaceous structure the garment and needs further investigation to confirm. None of the previous studies examined several knit structures and fiber contents at the same time. The reviewed literature did not specifically report on the appear retention variable. One study reported on the colorfastness to laundering [2]. The study found that colorfastness to staining improved between 5th and 25th washing. However, it deplored for colorfastness to color change for red cotton t-shirts.

Previous research on pilling resistance revealed that it was impacted by yarn type [9]-[12], decrease in pill formation over time after repeated laundering [2), singeing and fabric weight [13], adding polyester to cotton [4], and stitch length (6). Filament yarns were reported to fuzz more and staple yarns pill more in one study [9]. Compact yarns offered higher pilling resistance than the ring-spun yarns [10] [12]. Pilling resistance improved from 5th to 25th laundering [2].

Mule yarn pilled less than the ring spun yarn [11]. Compact yarn performed better than the ring-spun yarn for combed cotton [12]. Pilling was less for heavier weight and singed fabric [13]. Adding polyester to cotton enhanced its pilling resistance [4]. Increase in stitch length decreases pilling resistance [6]. Combed cotton had the least pilling [14]. The knowledge of pilling resistance was deemed important for determining quality of the fabric because it impacts appearance, texture and comfort [15]. Pilling was not presented in any of the previous work for different knit structures in variety of fiber contents to make choices and rationale of performance easier for the prospective consumers.

Only three studies were found that reported on stretch and/or recovery of knitted fabrics. Tamanna et al. (2017) reported that fabric count, thickness and weight impacted stretch and recovery of knitted fabrics [16]. Chowdhary compared jersey and interlock knits by the industrial and BS4294-1968 methods [17]. Findings revealed that % of spandex did not impact stretch % proportionately. It was 120% for the 5% and 9% spandex and 84% for 12% spandex in the crosswise direction. For jersey knits. It was similar for the lengthwise direction. Two interlock knits with same fiber content performed differently. Two blends with different fiber contents did not have similar performance. Poly/cotton blend stretched more that ha rayon/nylon/spandex interlock knit. Fabric count impacted stretch. However, results did not differ for two methods. In another study that examined spandex blends with cotton, polyester and rayon, Thickness did not impact stretch. However, fiber content did [18]. Rayon/spandex blend had the highest stretch. Cotton/spandex and polyester spandex dis not differ from each other. However, differences were significant between cotton/spandex and rayon/spandex as well as polyester/spandex and rayon/spandex based on the post-hoc comparisons.

Based on the literature review, following three research questions were developed. Research questions were answered using descriptive and inferential statistics to provide information for academicians, consumers, and industry specialists.

Research Question 1: Do interlock knits differ for their performance attributes such as appearance retention, dimensional stability, industrial stretch, pilling resistance, shade and stain change?

Research Question 2: Do jersey knits differ for their performance attributes such as appearance retention, dimensional stability, horizontal wicking, industrial stretch, pilling resistance, shade and stain change?

Research Question 3: Do pique knits differ for their performance attributes such as appearance retention, dimensional stability, industrial stretch, pilling resistance, shade and stain change?

III. METHODOLOGY

Several standardized and tested measures were used to collect data for the investigation. Details are outlined in table 1. Even though several studies reported on repeated launderings, none of the previous studied reported results after the first wash. Therefore, the test was modified to examine the impact after first wash only for dimensional stability and appearance retention. The assumption was that consumer must be satisfied after the first wash for continued use of the garment or repeat of purchase. Additionally, it allows manufacturers to give pre-treatments and optimally right the care label information.

TABLE I
Attributes, Test Standards, Specimen Size and Number

Attribute	Test Method	Specimen Size and Number
Fabric Weight	ASTM D 3776/3776M-2013 Reapproved 2017	5” x 5” (5)
Fabric Count	ASTM D 8007-2015	1”x1” (5)
Appearance Retention	AATCC 124 – 2014 (Modified, Observed after one wash)	15” x 15” (3 for 9 observations)
Colorfastness to Crocking	AATCC 8	5” x 2” on bias (5)
Dimensional Stability	AATCC 96-2012 (Modified, Observed after one wash)	15” x 15” (3 for 9 observations)
Pilling Resistance	ASTM D-3512-2016 (Modified)	4.125” x 4.125” (on bias, 5 specimens instead of 3)
Stretch	Industrial Chowdhary [17]	10” x 10” (5)

Number of specimens were increased from two to five for crocking test and 3-5 for pilling resistance to make them consistent with Merkel’s recommendation of 5 minimum [19]. Number of observations for appearance retention and dimensional stability were 9 each and for the remaining performance and structural attributes were 5. Both descriptive and inferential statistics were used to explain and understand data. The level of confidence for the inferential statistics. was established at 95%.

IV. RESULT AND DISCUSSION

Results are presented in descriptive and inferential section for three types (interlock, jersey and pique)of knits individually.

Research Question 1

Do interlock knits differ for their performance attributes such as appearance retention, dimensional stability, industrial stretch, pilling resistance, shade and stain change?

Descriptive: Interlock Knits

Results from descriptive statistics for three types of knits were as follows. Interlock knits had the highest shrinkage (13.78%) in lengthwise direction for low count and heavy weight Rayon/wool/acrylic blend and lowest for the medium count and medium weight 100% polyester (2.78%). See Table II. However, for crosswise direction, it was highest for polyester/spandex (95/5%) blend (.78) and lowest for the 100% polyester (0%) in medium count and weight. Appearance retention was best for medium count and heavy weight poly/Spandex (96/4%) blend and worst for 100% low count and medium weight cotton. Pilling resistance as best for poly/spandex blend (4.2 on a 5-point scale) and worst for 100% cotton and poly/acrylic (50/50) blend (1 each). Reviewed literature did not provide rationale for higher pilling of poly/acrylic blend. Cotton's poor pilling may be attributed to the use of staple fiber. Stretch was highest for 100% cotton and lowest for 100% polyester. Polyester is a filament and stronger than cotton that is a staple yarn [20].

Inferential: Interlock Knits

100% polyester cotton that were low count and medium weight differed significantly for appearance retention ($t_{16}=15.127$, $p<.05$), dimensional stability in length ($t_{16}=8.522$, $p<.05$), width ($t_{16}=7.655$, $p<.05$),

pilling resistance ($t_8= -5.251$, $p<.05$), and stretch ($t_8=21.467$, $p<.05$). 100% polyester passed for both color change and staining. However, no data were available for 100% cotton. Both polyester/spandex blends (95/5, and 96/4) passed the appearance retention test. However, 96/4 blend performed significantly better than the 95/5 blend (($t_{16}=15.148$, $p<.05$). Care label may need different ironing instructions for both. Both blends passed the dimensional stability test in the length direction. However, it grew significantly higher for 95/5 blend than the 96/4 blend for width ($t_{16}=9.624$, $p<.05$). Pilling was also higher for the former one. Spandex % appeared to make a difference. This finding needs further investigation in controlled setting.

Research Question 2

Do jersey knits differ for their performance attributes such as appearance retention, dimensional stability, horizontal wicking, industrial stretch, pilling resistance, shade and stain change?

Descriptive: Jersey Knits

Appearance retention was highest for cotton/polyester (60/40) and 45/55 (wool/ acrylic); followed by cotton/poly and poly spandex; by bamboo/spandex, cotton/poly (85/15), and low count medium weight poly/ spandex; and by 100% cotton [Table III). The findings were consistent with contention of text author who reported that blends offer better service including appearance [20] based on the fact that the addition of polyester can improve the appearance retention. Results were best for 60/40 polyester/cotton (3.667) and worst for the 100% cotton (2.222). It should be >3.5 for most of the end uses [21].

Medium weight and medium count poly/spandex (95/5) blends had better dimensional stability than low count medium weight blend in course direction. However, reverse was true for the wale direction. Differential shrinkage in lengthwise and crosswise direction was also reported by two previous studies [2], [3].

All fabrics failed for pilling. It was highest for 85/15 cotton/polyester and lowest for the bamboo/spandex. Stretch was the highest for the bamboo/spandex and the lowest for cotton/polyester (50/40 and 50/50). Color change and staining were best for the wool/acrylic blend.

Inferential: Jersey Knits

The t-test analysis performed for dimensional stability revealed that two polyester/spandex (95/5%) blends performed significantly differently from each other in the crosswise direction. ($t_{16} =7.475$, $p<.05$). However, differences were not significant for the wale direction. When compared three cotton blends with cotton using the one-way analysis of variance (ANOVA), results were significantly different ($F_{3, 32} = 95.238$, $p<.05$). So was true when three cotton blends were compared without cotton ($F_{2, 24}$, 9.447, $p<.05$). The post-hoc comparisons revealed that differences were significant between 85/15% and 50/50% cotton polyester blends ($t_8 =4.242$ $<p<.05$) and 60/40 and 85/15 blends ($t_8 =5.302$, $<p<.05$) for length. They were not different between 50/50 and 60/40 percent blends. All three differed significantly for the width direction.

These differences will be important to consider for high quality products. Otherwise, they all meet the minimum standard of 5% maximum. Bamboo/Spandex blend and 100% cotton shrank more than 5% in lengthwise direction and bamboo grew more than 5%

[21]. They must be pre-shrunk before making a wearable apparel for better post laundering performance and consumer satisfaction.

TABLE II
Descriptive Statistics for Interlock Knit

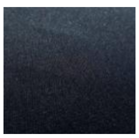
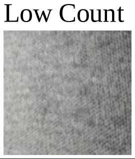
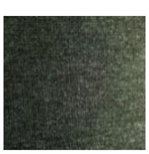
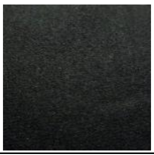
Interlock	**Appearance Retention** **M SD**	**Dimensional Stability** **M SD**	**Pilling Resistance** **M SD**	**Stretch** **M SD**	**Color Change** **M SD**
100% Cotton Medium Weight Low Count White Fabric	1.667 0.500	Wales 7.22 1.37 Courses -4.03 1.50	1 0	127 6.708	Staining N/A Color Change N/A
95/5% Poly/Spandex Medium Weight Medium Count 	3.667 0.250	Wales 3.75 0.88 Courses 9.72 3.01	3.6 .548	100 7.071	Staining 4.6 .548 Color Change 5 0
96/4 Poly/Spandex Heavy Weight Medium Count White Fabric	5 0.000	Wales 5 0.00 Courses 0 0.00	4.2 .447	98 10.954	Staining N/A Color Change N/A
50/50 Poly/Acrylic Medium Weight Low Count 	3.889 0.220	Wales 13.611 2.760 Courses -6.94 2.08	1 0	148 12.550	Staining 5 0 Color Change 5 0
100% Polyester Medium Weight Medium Count 	4.889 0.333	Wales 2.78 0.555 Courses 0.28 0.555	3.2 .837	55 0	Staining 4 0 Color Change 5 0
76/20/4 Rayon/Wool/Acrylic Heavy Weight Low Count 	4.00 0.000	Wales 13.78 1.46 Courses 6.750 2.47	3.2 .447	58 2.739	Staining 4.2 .447 Color Change 5 0

TABLE III
Descriptive Statistics for Jersey Knit

Jersey	**Appearance Retention** **M SD**	**Dimensional Stability** **M SD**	**Pilling Resistance** **M SD**	**Stretch** **M SD**	**Color Change** **M SD**
95/5 Bamboo/Spandex Heavy Weight Low Count White Fabric	3.167 0.250	Wales 19.444 1.67 Courses -11.11 3.50	1.4 .548	122 2.739	Staining N/A Color Change N/A
100% Cotton Light Weight Low Count 	2.222 0.441	Wales 7.5 0 0.00 Courses -4.17 1.25	2.4 .548	121 2.236	Staining 4 0 Color Change 4.4 .548
45/55 Wool/Acrylic Medium Weight Low Count 	3.667 0.250	Wales 3.61 1.46 Courses 3.30 1.65	1.8 .447	63 4.472	Staining 4.2 .447 Color Change 5 0
85/15 Cotton/Polyester Light Weight Low Count 	3.333 0.250	Wales 2.92 0.63 Courses 0 0.00	3.8 .447	84 5.477	Staining 3.2 .447 Color Change 4.6 .548
50/50 Cotton/Polyester Light Weight Low Count 	3.00 0.000	Wales 0.833 1.25 Courses 1.11 1.16	1.6 .548	69 2.236	Staining 4.6 .548 Color Change 4.6 .548
60/40 Cotton/Poly Light Weight Low Count 	3.667 0.250	Wales 1.25 1.25 Courses 2.64 0.98	1.8 .447	69 5.477	Staining 5 0 Color Change 4.8 .447
95/5 Poly/Spandex Medium Weight Low Count	3.000 0.00	Wales 5.83 1.25 Courses 9.861 3.01	2.4 .548	112 8.367	Staining 4.6 .548 Color Change

					3.4 .548
95/5 Poly/Spandex Medium Weight Medium Count 	3.333 0.250	Wales 6.25 1.08 Courses 1.25 1.25	3.4 .548	126 4.183	Staining 4.8 .447 Color Change 4.4 .894

Research Question 3

Do pique knits differ for their performance attributes such as appearance retention, dimensional stability, industrial stretch, pilling resistance, shade and stain change?

Descriptive: Pique Knits

Low count and medium weight cotton performed better than low count and light weight cotton for colorfastness to crocking, dimensional stability Table IV). However, low count light weight performed better for appearance retention, pilling resistance, and stretch than the medium weight low cotton pique knits. Light weight low count polyester performed better for colorfastness to crocking, dimensional stability and appearance retention but worse for stretch and pilling resistance.

Inferential: Pique Knits

Inferentially, light weight cotton performed better for pilling ($t8 = 2.044$, $p<.05$) and stretch ($t8 = 14.423$, $p<.05$) than the medium weight cotton Medium weight cotton performed better for dimensional stability in both directions than the light-weight cotton (($t8 = 6.327$, $p<.05$) for length, ($t8 = 6.481$ $p<.05$) for width). They performed better for colorfastness to staining ($t8 = 3.165$), $p<.05$), color change ($t8 = 1.899$, $p<.05$), and appearance retention (($t8 = 6.538$, $p<.05$).

Inferential comparison between cotton and polyester revealed that polyester performed better for appearance retention ($t8 = 14.68$, $p<.05$), staining ($t8 = 3.165$, $p<.05$), and color change ($t8 = 1.899$, $p<.05$). Cotton performed better than polyester for pilling ($t8 = 9.821$), $p<.05$), and stretch ($t8 = 17.636$, $p<.05$). For dimensional stability, polyester performed much better than cotton in both length ($t8 = 51.748$, $p<.05$) and width ($t8 = 19.424$, $p<.05$). Polyester's better performance for appearance retention can be attributed to the fact that it is made from filament and cotton is made from staple yarns [19}-[20]. It is well documented that solution dyeing of synthetics gives it better colorfastness than cotton.

Additional analysis to compare 100% low count and low weight cotton for pique and jersey knits as well as low count and medium weight pique and interlock knits. When compared for low count and low weight, the t-test analysis revealed that pique knit shrank more in length ($t8 = 6.656$, $p<.05$) and grew more in width ($t8 = 4.435$, $p<.05$) for pique than jersey knit. Appearance retention was better for jersey knit ($t8 = -.2.677$, $p<.05$) but pilling resistance ($t8 = 9.489$, $p<.05$) was better for pique knit than the jersey knit. Stretch was higher for jersey than the pique knit ($t8 = 6.761$, $p<.05$). All these were significant at the 95% confidence level.

When compared for low count and medium weight, the t-test analysis revealed that Pique knit had higher appearance retention ($t8 = 5.261$, $p<.05$) and pilling resistance ($t8 = 12.555$, $p<.05$) than the interlock knit. For dimensional stability, pique knit performed better than the interlock knit. However, they both filed for the lengthwise shrinkage. Interlock knit grew in the crosswise direction. Stretch was better for the interlock knit than the pique knit ($t8 = 6.761.$, $p<.05$).

V. CONCLUSION

Finding from the reported study, support some of the previous findings and refutes other. Some key findings are provided below. Difference in structural attributes like knit type, fabric weight and fabric count impacted the examined performance attributes differentially. All of the jersey fabrics failed for pilling resistance except for 85/15 (cotton/polyester) blend. In general, pilling was found to be higher for jersey than interlock and pique knits.

For interlock knits in the reported study, polyester/acrylic (50/50) had the best performance for colorfastness to crocking and stretch, 100% polyester and polyester/spandex (96/4%) for dimensional stability, and medium count heavy weight polyester/spandex (96/4%) for appearance retention and pilling resistance. In jersey knit, 60/40 cotton/polyester blend had the best performance for appearance retention and colorfastness to crocking for staining, wool/acrylic (45/55%) for colorfastness to color change, 50/50 (cotton/polyester) for dimensional stability in wales and 85/15 (cotton/polyester) for dimensional stability in courses, poly/spandex (95/5%) for stretch, and cotton/polyester (85/15%) for pilling resistance. For pique knit, low-count, light-weight 100% cotton had the best performance for stretch and pilling resistance; 100% polyester had the best performance for colorfastness to crocking and dimensional stability; and the medium weight cotton with low count performed at a mediocre level for all of the tested variables. Additional research is needed to further confirm these findings under strictly controlled conditions. For example, structural attributes could be controlled better by purchasing them from the textile manufacturer rather than retailer. This will allow to generalize findings better than found in the reported study. However, findings as such provide additional insight by providing evidence for some of the general assumptions used by the professionals. They also help consumers with understanding performance of different types of knits that may or may not perform similarly for various end uses. A majority of the previous research uses technical aspects of textile research. This study provides applied aspect to make it more conducive for both apparel retailers and consumers than offered by the existing literature. Lastly, it allows to better explore the impact of varying percentages of different fiber contents on selected performance attributes of textiles to provide refine the existing knowledge on the topic.

TABLE IV
Descriptive Statistics for Pique Knit

Pique	**Color Change** **M SD**	**Dimensional Stability** **M SD**	**Pilling Resistance** **M SD**	**Stretch** **M SD**	**Appearance Retention** **M SD**
100% Cotton Light Weight Low Count 	Staining 3.8 .447 Color Change 4.2 .447	Wales 13.89 1.92 Courses -8.33 1.40	5 0	101 5.477	1.33 .50
100% Cotton Medium Weight Low Count 	Staining 4.8 .447 Color Change 4.8 .447	Wales 9.17 0.88 Courses 2.69 1.98	4.44 .548	50 0	3.056 .167
100% Polyester Light Weight Low Count 	Staining 5 0 Color Change 5 0	Wales 1.39 0.98 Courses -0.78 1.91	2.8 .447	47 2.739	5.0 0

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