Comparison of Selected Structural and Performance Attributes of Cotton and Cotton/Polyester Blend T-Shirts

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Abstract

Consumers value care, comfort and durability while using textile products. This study compared two structural (fabric thickness and fabric weight) and four performance (air permeability, bursting strength, dimensional stability and horizontal wicking) attributes of cotton and cotton/polyester blend t-shirts before and after wash. Air permeability and horizontal wicking add to the comfort; bursting strength relates to durability and dimensional stability to care. Microsoft Excel and SPSS were executed to analyze the data. The blended t-shirt had significantly higher air permeability and bursting strength than the cotton t-shirt in unwashed form. For dimensional stability the only difference was detected in the neck opening. T-shirts differed significantly in their washed and unwashed forms for structural attributes and horizontal wicking. For Dimensional stability, the researcher used only the standard detergent for washing. Other detergents available in the market could be compared. This study revealed some useful information that could be used by apparel manufacturers, retailers and consumers. Other research methods like consumer survey or market research, wear test, and comparison thereof can be conducted more comprehensive understand of textiles for its intended uses.

Keywords - *Air Permeability, Bursting Strength, Dimensional Stability, Fabric Thickness, Fabric Weight, Horizontal Wicking, Cotton, Poly/ Cotton, T-shirts.*

I. INTRODUCTION

Comfort, care, durability and quality are important to consumer in apparel. Apparel manufacturers consider these attributes plus ease of stretch while designing apparel ([43]). Fabrics that stretch, have air permeability and moisture management, and dimensionally stable after refurbishing process serve consumers well ([12], [43], [33]). Consumer decision-making is based on both structural and performance attributes of an apparel product ([12], [21]). The purpose of the reported study was to examine air permeability, bursting strength, dimensional stability, fabric thickness, fabric weight and horizontal wicking of cotton and 50/50 cotton/polyester blended t-shirts in their washed and unwashed forms.

Several researchers have addressed the impact of fabric structure and care on the mechanical and performance attributes for a variety of fiber contents ([36], [3], [34], [14]). Some researchers focused on the impact of washing and drying conditions on the dimensional stability and distortion of knit fabrics ([42], [17], [3]). Herath and Kang ([23]) reported that an addition of the elastic materials like spandex to knits can impact dimensional stability.

Reviewed literature provided support for the importance of fabric wicking in knitted fabrics ([35]). Scholars in their literature demonstrate the effect of different polyester knit structures (rib, eyelet, interlock, and modified interlock) and fabric count on their wicking behaviour ([9]). Cil et al. ([14) examined comfort-related properties of cotton, acrylic and cotton-acrylic blends. In general, knit fabrics are used for several apparel items such as hats, socks, t-shirts, lingerie, scarves, ties etc. ([24]). The reason for this versatile is increased comfort from flexibility of knits.

Previous, literature on air permeability provided information on its relationship to fabric construction, and thickness ([44]); porosity/density ([8]) and different fiber content for non-woven materials ([16]). Other researchers found that the air permeability of a single jersey fabric was lower after washing. Increase in fabric weight and thickness increase after washing was reported by several scholars ([12], [44], [29]). Koc and Cincik, ([27]) studied bursting strength of polyester/viscose blended needle-punched nonwoven fabrics. Findings revealed that the increase of polyester fiber in the mixture enhanced the bursting strength.

Previously most of the literature focused on the structural and performance attributes of textiles for non-woven, woven and knitted materials in 100% fiber content except for addition of spandex in one study. None of the reviewed literature compared washed and unwashed cotton and cotton/polyester blend for air permeability, bursting strength, dimensional stability, fabric thickness, fabric weight and horizontal wicking. The reported study was undertaken to bridge the gap by studying what has been ignored in the previously published research.

Ball bursting strength test was introduced in 2015 and has not been yet reported at all in the previous studies. Knowledge of both structural and performance attributes is important for making informed decisions by manufacturers, consumers and retailer for 100% cotton and 50/50 blend from cotton and polyester.

II. LITERATURE REVIEW

The fast changing demands for comfort in fashion has resulted in use of knits in casual apparel more extensively than ever before. People use several different criteria while purchasing textile products. Some examples include color, size or fitness, new trends, comfort, brands, price, quality, customer satisfaction and durability. Strengthening air permeability, bursting strength, dimensional stability, and horizontal wicking can induce fabric comfort, care, and durability. Therefore, the literature review section was organized in the following six categories: air permeability, bursting strength, dimensional stability, fabric thickness, fabric weight and horizontal wicking.

A. Air Permeability

Air permeability is one of the categories used to test fabrics. Bhattacharya and Ajmeri ([8]) defined air permeability as the volume of air in millilitres, which passed in one second through 100mm^2 of the textile at a pressure variance of 10mm heads of water. They found a positive relationship between air permeability and water vapor permeability. Zhu, Kremenakova, Wang and Militky ([44]) stated that air permeability is one of the most important qualities for nonwovens. It varies by porosity and density, thickness, and pressure gradient. In their study, the result showed that air permeability decreases with an increase in thickness. Air permeability is frequently used in calculating and comparing the passage of air in various coated and uncoated fabrics for several end uses, such as waterproof coats, tents, and uniform shirting ([29]). Ogulata ([32]) stated that fabric weight and construction, especially thickness and porosity impact air permeability.

B. Bursting Strength

Mechanical and physical properties of knitted fabric influence durability and appearance of textiles. Bursting strength is to the knitted fabrics as breaking strength is to the woven fabrics. It impacts durability of fabrics. Therefore, bursting strength was chosen for testing knitted t-shirts.

Bursting strength can be defined as fabric resistance when the fabrics are subjected to a unidirectional, evenly distributed, growing compression load ([27]). Bursting strength of fabrics decreases with an increase of the fabric`s extensibility ([20]). Keiser and Garner ([26]) saw its use to determine appropriateness of the fabric for its intended end use. Badgett ([45]) compared bursting strength among three brands using the diaphragm inflation burst method and found that all brands differed significantly five laundry cycles.

As evident from preceding discussion, very limited work is reported on bursting strength. The test reported by Badgett ([45]) used a different standard than used in the reported study. The diaphragm method is appropriate only for knitted fabrics. The newly introduced ASTM D 6797 – 2015 (used for the current study) can be used for both knitted and woven fabrics ([6]).

C. Dimensional Stability

Dimensional stability is an important textile attribute. To keep a textile clean, it is laundered frequently. Laundering can make knitted materials shrink and/or grow. Chowdhary ([12]) compared three brands of t-shirts for their dimensional stability along with several other variables with standard and commercial detergents after 25 launderings. Her findings revealed that post-laundered fabric shrank differentially at different body parts, was thicker and heavier and had higher fabric count than the pre-laundered state. Differences existed between standard and commercial detergents. Badgett ([45]) also evaluated t-shirts and found that the shrinkage in the lengthwise dimension improved progressively over the course of laundry cycles.

Onal and Candan ([34]) reported that shrinkage in knitted materials is a severe problem, and is impacted by relaxation, dyeing and finishing. Suh ([42]) noted that stitch length, machine gauge, washing and drying method umpact the shrinking ability of knit fabric. Collier and Epps ([18]) mentioned three types of shrinkage which may occure when testiles are exposed to heat and/or moisture. The three types of shrinkage are relaxation, progressive and thermal shrinkage. Relaxation shrinkage occurs from the relaxation of stresses enforced for the period of weaving or knitting of the fabric,whereas progressive shrinkage is dimensional change that lasts throughout successive washings. On the other hand, thermal shrinkage is restricted to textiles composed of thermoplastic filaments, such as acetate, polyester and nylon. Quaynor, Takahashi and Nakajima ([46]) suggested to to consider relaxation shrinkage when using knitted materials.

Swan & Combs ([39]) reported that consumer satisfaction depends on instrumental and expressive outcomes when they purchased clothes. Instrumental outcomes included durability, laundering properties, warm or cool to wear, retention of shape, color, and wrinkle resistance; and the expressive outcomes were styling, responses of people to the item, comfort and color ([3]). An impact of repeated laundering on knitted fabric was also emphasized.

D. Fabric Thickness and Fabric Weight

Structural attributes include both fabric thickness and fabric weight. Fabric thickness and fabric weight can impact textile performance ([12]). She reported that shrinkage increases fabric count and weight after laundering. Fabrics that are lightweight and thicker could be more comfortable than lightweight and thinner fabrics. Chowdhary and Vijaykumar ([13]) found that washed fabrics had higher thickness and fabric weight than the unwashed fabrics. Keiser & Garner ([26]) found that bulkiness of a knit fabric is dependent on the thickness of the yarn. Multiple researchers showed that fabric weight is used to determine cost and quality, and appropriateness for the intended use and ease for the wearer ([41], [10], [25]).

E. Horizontal Wicking

The human body in motion is affected by fabric construction and related properties ([15]). Knitting technology has improved in the past few decades. More people are using knits for their simple production techniques, low-cost, high levels of clothing comfort and wide product range than woven fabrics. Active wear, casual wear, sportswear and underwear, knit fabrics are some of the end-uses ([33]).Moisture and thermal comfort of clothing systems are function of the wetting and wicking behaviors ([22]). The authors mentioned that a clothing system with high wicking capacity can provide solace through evaporative cooling from rapid exchange of moisture.

Overall, the literature review revealed that researchers used several different fiber contents and tests. Very few researchers mentioned the before and after wash of fabric and their consequences. The study reported here compared cotton and cotton/polyester blend t-shirts for selected structural and performance attributes. Today blends are gaining popularity both in mass, as well as designer clothing. Therefore, it is a topic worthy of study.

Based on the literature review two sets of hypotheses were developed. Set a compared two-fiber content and set b compared washed unwashed condition.

Set 1

Hypothesis 1: Cotton and cotton/polyester blend t-shirts will not differ for air permeability.
Hypothesis 2: Cotton and cotton/polyester blend t-shirts will not differ for bursting strength.
Hypothesis 3: Cotton and cotton/polyester blend t-shirts will differ for dimensional stability.
Hypothesis 4: Cotton and cotton/polyester blend t-shirts will not differ for fabric thickness.
Hypothesis 5: Cotton and cotton/polyester blend t-shirts will not differ for fabric weight.
Hypothesis 6: Cotton and cotton/polyester blend t-shirts will differ for horizontal wicking.

Set 2

Hypothesis 1: No difference will exist for two fiber content in before and after wash for air permeability.
Hypothesis 2: No difference will exist for two fiber content in before and after was for bursting strength.
Hypothesis 3: No difference will exist for two fiber content in before and after wash for dimensional stability.
Hypothesis 4: No difference will exist for two fiber content in before and after wash for fabric thickness.
Hypothesis 5: No difference will exist for two fiber content in before and after wash for fabric weight.
Hypothesis 6: No difference will exist for two fiber content in before and after wash for horizontal wicking.

III. MATERIALS AND METHODS

Cotton (100%) and Cotton/Poly (50/50) t-shirts were tested for selected structural and performance attributes in both washed and unwashed forms. Five XL t-shirts were selected for each fiber content. A total of ten t-shirts were compared in washed and unwashed forms except for dimensional stability. In unwashed form, the researcher performed six tests and after washing ten t-shirts with detergent, the researcher performed five tests. Standard ASTM and AATCC test were performed. The reported study examined air permeability, bursting strength, dimensional stability and horizontal wicking as performance attributes. Fabric thickness and fabric weight were selected as the structural attributes. All T-shirts were conditioned under the standard atmospheric conditions of 21 $\pm$ 1 C and 65$\pm$ 2 % of humidity for least 12 hours. The collected data are continuous variables from independent samples. However, due to small sample size, Mann-Whitney U test was used ([37]). For the independent samples, Mann-Whitney U test is the non-parametric alternative to the t-test. Mann Whitney U test compares medians instead of means into two groups, which converts the scores on the continuous variable to rank through the two groups. It tests whether the median grades for the two groups differ significantly. A 95% level of confidence was established to accept or reject the hypotheses. Microsoft Excel and SPSS was executed to analyze the data. For this research, the total number of t-shirts were twelve. Five t-shirts for each fiber content were used for analysis. All of the t-shirts were examined before and after wash. Five specimens are an acceptable number in industry ([30]). All tests and specimens' details are shown in Table 1.

TABLE 1: Details of Test Standard

SI. No.	Test	Method	Specimen Size
1	Air Permeability	ASTM-D737-2016[7]	N/A
2	Bursting Strength	ASTM D6797-2015[6]	5"X5"
3	Dimensional Stability & Fabric Shrinkage	AATCC 135-2015[1] & ASTM D6321-2015[6]	N/A
4	Fabric Thickness	ASTM D1777-2011[5]	N/A
5	Fabric Weight	ASTM D 3776-2002[4]	5"X5"
6	Horizontal Wicking	AATCC 198-2016[2]	8''X8"

IV. RESULTS AND DISCUSSION

One hundred percent cotton 50% cotton/50% polyester blend were used for the study by testing two sets of hypotheses. Set a compared two fiber contents in unwashed forms and set b compared hypotheses for pre-post wash conditions. Median, Mann Whitney U value, and probability were recorded to test hypotheses.

Set a

Hypothesis 1: Cotton and cotton/polyester blend t-shirts will not differ for air permeability.

Based on MWU test, the medians for the two fabrics differed significantly for air permeability ($p=.009<0.05$). See Table 2. Hundred percent cotton had lower median (107.4 $ft^3/min/ft^2$) in air permeability than the blend t-shirt (151.8 $ft^3/min/ft^2$). Hypotheses 1 was rejected.

Table 2: Comparison of Unwashed 100% Cotton and 50% Cotton/50% Polyester through Median, Mann-Whitney Value, and Probability for Air permeability, Bursting Strength, Fabric Thickness, Fabric Weight and Horizontal Wicking.

No	Attribute	Fabric type	Median	Mann-Whitney Value	Probability value
1	Air permeability	100% Cotton	107.4 $ft^3/ft^2/min$	0.000	0.009
		50% CTN 50% POLY	151.8 $ft^3/ft^2/min$		
2	Bursting Strength	100% Cotton	5161.59 psi	3.000	0.047
		50% CTN 50% POLY	10646.74 psi		
4	Fabric Thickness	100% Cotton	0.588 mm	4.000	0.076
		50% CTN 50% POLY	0.62 mm		
5	Fabric Weight	100% Cotton	168.784 gram	0.000	0.009
		50% CTN 50% POLY	186.084 gram		
6	Horizontal Wicking	100% Cotton	0.84823 mm	9.000	0.459
		50% CTN 50% POLY	0.75398 mm		

Table 3: Comparison of Unwashed 100% Cotton and 50% Cotton/50% Polyester through Median, Mann-Whitney Value, and Probability for Dimensional Stability.

No 3	Attribute	Fabric type	Measurement Area	Median	Mann-Whitney Value	Probability value
1	Dimensional Stability	100% Cotton	Chest Width	58.8 cm	11.5	0.834
		50% CTN 50% POLY		58.8 cm		
2	Dimensional Stability	100% Cotton	Front Length	58.2 cm	3.5	0.056
		50% CTN 50% POLY		57 cm		
3	Dimensional Stability	100% Cotton	Sleeve Length	20.8 cm	8.5	0.396
		50% CTN 50% POLY		20.2 cm		
4	Dimensional Stability	100% Cotton	Sleeve Seam	28.5 cm	11	0.752
		50% CTN 50% POLY		28.5 cm		
5	Dimensional Stability	100% Cotton	Sleeve Opening	22 cm	10.5	0.67
		50% CTN 50% POLY		21.5 cm		
6	Dimensional Stability	100% Cotton	Neck Opening	21 cm	2.5	0.036
		50% CTN 50% POLY		23.4 cm		

Hypothesis 2: Cotton and polyester/ cotton blend t-shirts will not differ for bursting strength.

Based on MWU test, the medians for the two fabrics differed significantly for bursting strength (p=.047<0.05). See Table 2. Blend t-shirt had higher median (10646.74 psi) in bursting strength than the 100% cotton t-shirt (5161.59 psi). Hypotheses 2 was rejected.

Hypotheses 3: Cotton and polyester/ cotton blend t-shirts will differ for dimensional stability.

Based on MWU test, the medians for the two fabrics do not differ for chest width, front length, sleeve length, sleeve seam, sleeve opening. The differences is only for neck opening (p= 0.036< 0.05). See Table 3. Hundred percent cotton had lower median (21cm) in dimensional stability than the blend t-shirt (23.4cm). The alternative hypotheses partially rejected.

Hypotheses 4: Cotton and polyester/ cotton blend t-shirt will not differ for fabric thickness.

Based on MWU test, there was no median difference between the two unwashed fabrics for fabric thickness (p=.076>0.05). See Table 2. Blend and 100% cotton t-shirts had the same medians in fabric thickness (0.62 mm and 0.588 mm). Hypothesis 4 was accepted.

Hypotheses 5: Cotton and polyester/ cotton blend t-shirt will not differ for fabric weight.

Based on MWU test, the medians for two fabrics differed significantly for fabric weight (p=.009<0.05). See Table 2. 100% cotton had lower median (168.784 gram) in fabric weight than the blend t-shirt (186.084 gram). Hypotheses 5 was rejected.

Hypotheses 6: Cotton and polyester/ cotton blend t-shirts will differ for horizontal wicking.

Based on MWU test, there was no median difference between the two unwashed fabrics for horizontal wicking (p=.459>0.05). See Table 2. Blend and 100% cotton t-shirts had same medians in wicking rate (0.75398 mm and 0.84823 mm). Hypothesis 6 was rejected.

Table 4: Comparison of Washed and Unwashed 100% Cotton Through Median, Mann Whitney Value and Probability for Air Permeability, Bursting Strength, Fabric Thickness, Fabric Weight and Horizontal Wicking.

No	Attribute	Fabric type	Median	Mann-Whitney Value	Probability value
1	Air permeability	Unwashed	107.4 $ft^3/ft^2/min$	0.000	0.009
		Washed	90.64 $ft^3/ft^2/min$		
2	Bursting Strength	Unwashed	5161.59 psi	5.000	0.221
		Washed	6222.49 psi		
4	Fabric Thickness	Unwashed	0.588 mm	0.000	0.009
		Washed	0.86 mm		
5	Fabric Weight	Unwashed	168.784 gram	0.000	0.009
		Washed	179.635 gram		
6	Horizontal Wicking	Unwashed	0.84823 mm	0.000	0.009
		Washed	22.834196 mm		

Table 5: Comparison of Washed and Unwashed 100% Cotton through Median, Mann-Whitney Value and Probability for Dimensional Stability.

No 3	Attribute	Fabric type	Measurement Area	Median	Mann-Whitney Value	Probability value
1	Dimensional Stability	unwashed	Chest Width	58.8 cm	0	0.009
		Washed		55.2 cm		
2	Dimensional Stability	unwashed	Front Length	58.2 cm	0	0.009
		Washed		54 cm		
3	Dimensional Stability	unwashed	Sleeve Length	20.8 cm	1.5	0.018
		Washed		20 cm		
4	Dimensional Stability	unwashed	Sleeve Seam	28.5 cm	0.5	0.012
		Washed		27 cm		
5	Dimensional Stability	unwashed	Sleeve Opening	22 cm	3	0.044
		Washed		21.3 cm		
6	Dimensional Stability	unwashed	Neck Opening	21 cm	5	0.112
		Washed		19 cm		

Table 6: Comparison of Washed and Unwashed 50% Cotton/50% Polyester Blend Through Median, Mann-Whitney Value and Probability for Air Permeability, Bursting Strength, Fabric Thickness, Fabric Weight and Horizontal Wicking.

No	Attribute	Fabric type	Median	Mann-Whitney Value	Probability value
1	Air permeability	Unwashed	151.8 $ft^3/ft^2/min$	0	0.009
		Washed	124 $ft^3/ft^2/min$		
2	Bursting Strength	Unwashed	10646.74 psi	12	0.917
		Washed	7898.75 psi		
4	Fabric Thickness	Unwashed	0.62 mm	0	0.009
		Washed	0.836 mm		
5	Fabric Weight	Unwashed	186.084 gram	0	0.009
		Washed	200.16 gram		
6	Horizontal Wicking	Unwashed	0.75398 mm	0	0.009
		Washed	24.62229 mm		

Table 7: Comparison of Washed and Unwashed 50% Cotton/50% Polyester Blend Through Median, Mann-Whitney Value and Probability for Dimensional Stability.

No 3	Attribute	Fabric type	Measurement Area	Median	Mann-Whitney Value	Probability value
1	Dimensional Stability	unwashed	Chest Width	58.8 cm	0	0.009
		Washed		57.3 cm		
2	Dimensional Stability	unwashed	Front Length	57 cm	0	0.008
		Washed		55.2 cm		
3	Dimensional Stability	unwashed	Sleeve Length	20.2 cm	2.5	0.033
		Washed		19.5 cm		
4	Dimensional Stability	unwashed	Sleeve Seam	28.5 cm	0	0.009
		Washed		26.7 cm		
5	Dimensional Stability	unwashed	Sleeve Opening	21.5 cm	3	0.042
		Washed		21 cm		
6	Dimensional Stability	unwashed	Neck Opening	23.4 cm	0	0.009
		Washed		21 cm		

Set 2

Hypothesis 1: No difference will exist for two-fiber contents in before and after wash for air permeability.

Based on MWU test, the medians for the washed and unwashed for 100% cotton fabrics differed significantly for air permeability (p=.009 <0.05). See Table 4. Hundred percent cotton washed had lower median (90.64 $ft^3/min/ft^2$) in air permeability than the 100% cotton unwashed (107.4 $ft^3/min/ft^2$). On the other hand, the medians for the washed and unwashed for 50% cotton 50% polyester fabrics also differed significantly for air permeability (p=.009 <0.05).See Table 6. Fifty percent cotton 50% polyester blend washed had lower median (124 $ft^3/min/ft^2$) in air permeability than the 50% cotton 50% polyester unwashed (151.8 $ft^3/min/ft^2$). Hypotheses 1 was rejected.

Hypotheses 2: No difference will exist for two-fiber content in before and after wash for bursting strength.

Based on MWU test, there was no median difference between the washed and unwashed 100% cotton fabrics for bursting strength (p=0.221>0.05). See Table 4. Hundred percent cotton washed and unwashed had almost same medians in bursting strength (5161.59 psi and 6222.49 psi). On the other hand, the medians for the washed and unwashed for 50% cotton 50% polyester fabrics also had no difference for bursting strength (p=0.917 >0.05).See Table 6. Fifty percent cotton 50% polyester blend washed and unwashed had almost same median in bursting strength (10646.74 psi and 7898.75 psi). Hypothesis 2 was accepted.

Hypotheses 3: No difference will exist for two-fiber contents before and after wash for dimensional stability.

Based on MWU test the medians for the washed and unwashed for 100% cotton fabrics was different for chest width, front length, sleeve length, sleeve seam, sleeve opening. However, it did not differ for neck opening. See Table 5. Hundred percent cotton unwashed had a higher median (21 cm) in dimensional stability than the 100% cotton washed t-shirt (19 cm). On the other hand, the medians for the washed and unwashed for 50% cotton 50% polyester blend fabrics was different for chest width, front length, sleeve length, sleeve seam, sleeve opening, neck opening. See Table 7.Null hypotheses was rejected.

Hypotheses 4: No difference will exist for two-fiber contents in before and after wash for fabric thickness.

Based on MWU test, the medians for the washed and unwashed for 100% cotton fabrics differed significantly for fabric thickness (p=.009 <0.05). See Table 4. Hundred percent cotton washed had higher median (0.86mm) in fabric thickness than the 100% cotton unwashed (0.588 mm). On the other hand, the medians for the washed and unwashed for 50% cotton 50% polyester fabrics also differed significantly for fabric thickness (p=.009 <0.05). See Table 6. Fifty percent cotton 50% polyester blend washed had a higher median (0.836mm) in fabric thickness than the 50% cotton 50% polyester unwashed (0.62 mm). Hypotheses 4 was rejected.

Hypotheses 5: No difference will exist for two-fiber contents in before and after wash for fabric weight.

Based on MWU test, the medians for the washed and unwashed for 100% cotton fabrics differed significantly for fabric weight (p=.009 <0.05). See Table 4. Hundred percent cotton washed had higher median (179.635 gram) in fabric weight than the 100% cotton unwashed (168.784 gram). On the other hand, the medians for the washed and unwashed for 50% cotton 50% polyester fabrics also differed significantly for fabric weight (p=.009 <0.05). See Table 6. Fifty percent cotton 50% polyester blend washed had a higher median (200.16 gram) in fabric thickness than the 50% cotton 50% polyester unwashed (186.084 gram). Hypotheses 5 was rejected.

Hypotheses 6: No difference will exist for two-fiber contents in before and after wash for horizontal wicking.

Based on MWU test, the medians for the washed and unwashed for 100% cotton fabrics differed significantly for horizontal wicking (p=.009 <0.05). See Table 4. Hundred percent cotton washed had higher median (22.834196 mm) in horizontal wicking than the 100% cotton unwashed (0.848232 mm). On the other hand, the medians for the washed and unwashed for 50% cotton 50% polyester fabrics also differed significantly for horizontal wicking (p=.009 <0.05). See Table 6. Fifty percent cotton 50% polyester blend washed had higher median (24.62229 mm) in horizontal wicking than the 50% cotton 50% polyester unwashed (0.753984 mm). Hypotheses 6 was rejected.

V. DISCUSSION

This section compared findings from this investigation to previous studies reviewed for the literature. Results from the study provided support for some of the previous research, found some inconsistencies, and added new information.

In this study, air permeability of washed and unwashed t-shirts after five launderings was compared. Results revealed that the blended t-shirt had significantly higher permeability than the cotton t-shirt in unwashed form. However, both fiber contents differed significantly when compared for washed and unwashed settings. None of the reviewed literature on air permeability tested knits. Zhu et al. ([44]) reported that fabric density and thickness impact air permeability for nonwoven fabrics. Reduced air permeability after washing for both fiber contents in the reported study could be function of increased thickness in the washed form ([12]). Increased thickness reduces porosity and can result in decreased air permeability.

In this research, regarding bursting strength, the researcher found that the unwashed fabrics of 100% cotton and 50% cotton/50% polyester differed significantly whereas no difference was found for both washed and unwashed cotton and poly cotton blend. Results revealed that the blended t-shirt had significantly higher bursting strength than the cotton t-shirt. However, both fiber contents differed significantly when compared for washed and unwashed settings. Badgett ([45]) used the diaphragm inflation burst method for her research whereas this study used ball-burst method. Therefore, no comparison could be made. However, it will be good to compare results of two methods in future study. Ertugrul and Ucar ([20]) mentioned that the tightness factor of fabrics' extensibility affects its bursting strength and they show an inverse relation. They did not mention the impact of fiber content on bursting strength. This finding may be consistent with this research for unwashed fabrics. After wash, both of the fabrics gained more density that could have influenced the fabric's bursting strength.

Dimensional stability for chest width, front length, sleeve length, sleeve seam and sleeve opening for the two fabrics did differ in unwashed form except for the neck opening. Chowdhary ([12]) examined dimensional changes with standard and commercial detergent after 5th and 25th washes. Changes were significant for chest width, front length, sleeve length and neck opening for various brands. Except for the neck opening change, findings of the reported study were consistent with Chowdhary's ([12]) findings. Chowdhary ([12]) mentioned that dimensional stability was affected even after the 5th wash. Chowdhary examined up to 25 laundry cycles because consumer does not throw away t-shirts after five washes. However, the reported study used only five cycles.

Collier and Epps ([18]) reported five percent as the acceptable shrinkage for knitted fabrics. Percentage shrinkage at various body areas for cotton ranged from 3.18% (sleeve opening) to 9.52% (neck opening). See table 9. Based on five percent parameter, cotton failed for four (chest, front length, sleeve seam and neck opening) of the six areas. The shrinkage for blended t-shirts ranged from 2.32% (sleeve opening) to 10.25% (neck opening). The blended t-shirt passed in four of the six areas (chest, sleeve opening, front length and sleeve length).

Table 9. Shrinkage % of Cotton and Cotton Polyester Blend T-shirts.

Measurement Area	Shrinkage% Cotton	Shrinkage% Blend
Chest Width	6.12%	2.55%
Front Length	7.21%	3.16%
Sleeve Length	3.84%	3.46%
Sleeve Opening	3.18%	2.32%
Sleeve Seam	7.32%	6.31%
Neck Opening	9.52%	10.25%

There was no difference found for fabric thickness between unwashed fabrics. However, both washed and unwashed cotton and cotton/polyester blend were statistically significant for fabric thickness. Chowdhary ([12]) found that fabric thickness increased significantly for two of the three brands. It was attributed to shrinkage of fabric and / or residue of detergent left on the fabric. This finding is consistent with the results of the reported study

For fabric weight, the researcher found the unwashed fabrics of 100% cotton and 50% cotton/50% polyester differed significantly. On the other hand, both washed and unwashed cotton and 50/50 cotton/poly blend were also statistically significant. Washed specimens were heavier than the unwashed ones. These findings are consistent with Chowdhary ([12]) who found that fabric weight increased for all three brands of cotton t-shirts between unwashed and washed ones (after 25 washes). Increase in weight could be function of shrinkage and residue from detergent after laundering ([12]). Shrinkage increases fabric count and thickness that can result in increased fabric weight.

For horizontal wicking, there was no difference between the two unwashed fabrics. In contrast, the washed and unwashed for 100% cotton and 50% cotton /50% poly blend fabrics differed significantly for horizontal wicking. This finding is consistent with Chowdhary ([12]) who found that horizontal wicking between 5th and 25th wash improved for all three brands. No justification was provided by Chowdhary for increased horizontal wicking after washing

VI. SUMMARY AND CONCLUSION

This research work mainly focuses on the structural and performance attributes of cotton and cotton/polyester blend t-shirts with different variables (air permeability, bursting strength, dimensional stability, fabric thickness, fabric weight and horizontal wicking) in washed and unwashed forms. The results showed that unwashed 100% cotton fabric performed lower in air permeability, bursting strength, dimensional stability, and fabric weight, whereas unwashed blend fabric performed better for all these variables. Differences were found for two fiber contents for air permeability, fabric thickness, fabric weight and horizontal wicking in washed and unwashed form. In contrast, no differences were found for two fiber contents for bursting strength in washed and unwashed form. However, dimensional stability was significantly different at neck opening only for 100% cotton t-shirts.

Air permeability was lower after washing for both fiber contents than in the unwashed form. Additionally, fabric thickness increased after washing for both fiber contents. Decrease in the air permeability could have been caused by the increased of thickness after washing from shrinkage. The unwashed blend t-shirt had higher bursting strength than the unwashed 100% cotton t-shirt. This difference may be attributed to the presence of polyester that is stronger than cotton. In contrast both fiber contents behaved similar in washed and unwashed form. Five wash cycles did not impact the fabric's ability to withstand perpendicular pressure regardless of their fiber content. There were differences found in both fiber contents for the unwashed form and washed form for dimensional stability for majority of the garment areas. Washing conditions can also impact the dimensional changes of single jersey materials. Therefore, it is possible to have different results in two research studies that used different temperatures.

Both of the fiber contents differed significantly for fabric weight in before and after wash forms. This implies that fabric weight could be a function of shrinkage and residue from detergent after laundering ([12]). In general, knitted fabric has good absorbency. In this present study, the wicking rate differed after washing for both fiber content. This indicates that the length of the wicking predominantly increases when laundering cycle increases ([40]).

To conclude, the reported study revealed that cotton t-shirts were better for bursting strength after washing than the unwashed form. However, bursting strength of the blended t-shirt was higher than cotton in both washed and unwashed forms. Both became better for horizontal wicking after washing. However, air permeability decreased for both fiber contents after washing. Both had higher fabric thickness and weight after washing. Dimensional stability was found to be better for blended t-shirts than the cotton t-shirts. These findings should be useful for manufacturers and consumers alike to understand comfort care and durability.

VII. IMPLICATIONS FOR FUTURE

Results from the study have implications for future research. Some of the strengths of the reported study include extending previous work to compare textiles in washed and unwashed form by comparing 100% cotton and 50/50 cotton/polyester blend, to examine bursting strength using the latest test method, to test air permeability for jersey knit, and to determine horizontal wicking for blend. Same variables can also be tested for different knit (interlock, pique, rib) and woven (plain, twill, satin) constructions. Additionally, other fiber contents can also be examined for in depth understanding of the selected structural and performance attributes. In this study, the researcher used only the standard detergent for washing. For future research, commercial (including organic and different brands) detergent or any other cleaning soap with or without additives could be examined. For laundering, this study only focused on fabric care label instruction. For further research, different washing and drying conditions can be tested. The study could be extended to include colourfastness to crocking, appearance retention, fabric count, tensile strength, tear strength, pilling, and seam strength.

This study was limited to laboratory testing. Useful information can be obtained by doing field or service testing. Additionally, a consumer survey or market research can be conducted to determine what is valued the most by consumer before selecting tests for the study. Methodologically, work reinforced the importance of using standardized test methods developed by AATCC and ASTM.

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