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RESEARCH ARTICLE

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Effect of cotton-polyester composite yarn on the physico-mechanical and comfort properties of woven fabric

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Abstract

Cotton is the most widely used natural cellulosic polymer and polyester is a synthetic polymer. The use of polyester fiber is increasing gradually day by day due to its strength and longevity, while the use of cotton fiber is decreasing due to its unavailability. At present, the use of cotton-polyester composites is ubiquitous. This research work aims to assess the physical, mechanical and comfort properties of the woven fabric using cotton-polyester composite yarns in a weft direction and coarser yarn count because of the use of these fabrics in the future for the denim manufacturing process. Four different samples were fabricated by using 100% cotton (10 Ne) yarn in the warp direction and 100% cotton, cotton-polyester composite, and 100% polyester yarn in the weft direction of the fabric. Similar fabric and machine parameters were maintained for manufacturing all the samples. The samples were then tested for areal density, tensile strength, thickness, abrasion resistance and pilling, drape, flexural rigidity, and air permeability to find the optimum capability of the fabric. Physico-mechanical properties with the proportion of increasing polyester components in fabrics improves areal density (184 to 199 g/m^2), strength (almost 19 times in weft direction), drape (0.655% to 0.789%), and flexural rigidity (almost double). On the other hand, increasing comfortability properties with the proportion of cotton components in fabrics improve air permeability (139.85 to 159.58 cc/s/cm^2), abrasion (only 3.036% mass loss), and pilling resistance (grading 4 after 2000 cycles).

Highlights

- Composite yarns made of cotton and polyester provide a method of improving fabric properties for better performance.
- Higher proportions of cotton make clothes more breathable and less likely to pill and wear out.
- Polyester parts make fabrics stronger, more durable, and less likely to wear out.

- Cotton-polyester composites are ideal and have potential for various textile applications.
- Blending natural and synthetic fibers composite allows for customized fabrics that meet specific performance needs without compromising comfort.

KEYWORDS

abrasion resistance, air permeability, flexural rigidity, tensile strength

1 | INTRODUCTION

Woven fabric is widely used in industrial applications such as textiles, sports, and military. Weaving allows for the production of a wide range of variations. Woven textiles are typically more resilient, easily cut into various forms, and work well for creating fashion trends for clothing.[1,2] The characteristics of the fiber and the spinning process affect the yarn, and the weave structure, warp and weft densities of the woven fabrics affect the fabric qualities.[3] For generations, the softness and breathability of cotton a natural fiber with many uses have made it an indispensable component of garments and textiles all over the globe.[4,5] The practice of cultivating it dates back millennia, to the time of the first known human societies. Cotton has long been associated with all things warm and sturdy from soft bedsheets to long-lasting denim. The most crucial raw material for woven garments is cotton. Cotton fibers have several advantages over other cellulose fibers, including superior durability, chemical stability, and resistance to damage from mild acids and alkalis over time.[6] Its high water absorption ability allows it to absorb up to 27% of the water in a humid environment without becoming wet.[7] For these reasons, cotton has been widely used in woven fabrics from the past to the present. On the other hand, nowadays, polyester (also known as polyethylene terephthalate or PET) fibers rule the global synthetic fiber market. Polyester has changed the way clothes are made because of how long they last and how well they resist wrinkles.[8,9] Its low price and ease of care make it suitable for a wide range of uses, from apparel to home furnishings. Polyester has become a go to for people who want durable, low-maintenance fabrics.[10] Polyester has nearly identical mechanical characteristics under standard conditions and in the wet state which make it an extremely valuable material. PET fibers are remarkably resistant to microbial invasion, acids, and alkalis.[11,12] Additionally, they are well-resistant to actinic deterioration and light. For this, the use of polyester fiber in woven cloth increasing day by day.

The purpose of this research is to fill in the gaps by finding the prepared composite's mechanical and comfort features so that the potential use of the composite can be forecasted. Also, in understanding woven fabric's physical properties that are affected by yarns that are blended with cotton and polyester to composite. There is an absence of in-depth studies that explore the connection between blend ratios of cotton-polyester composites, yarn structures, and particular fabric properties, though there is some research on the topic.[13–16] Furthermore, there is a lack of knowledge about the effects of different composite blending ratios on fabric performance. In light of recent innovations in textile production methods and novel fiber blends, it is important to assess the impact of these developments on fabric properties. This study's overarching goal is to learn more about the effects of modern composite blending techniques and technologies on fabric performance in terms of comfort, functionality and sustainability.

The fabric was constructed in four distinct ways with a warp of 100% cotton (10 Ne) and a weft of 100% cotton, cotton-polyester blend composites, or polyester yarn. For the production of each sample, the same fabric and machine settings were used. The samples were subsequently evaluated in mechanical and comfort properties such as areal density, tensile strength, thickness, abrasion resistance, pilling, drape, flexural rigidity, and air permeability to determine the fabric's greatest potential.

2 | MATERIALS AND METHODS

2.1 | Yarn specification

100% cotton is used as the warp yarn. A cheese package is used for this purpose which count is 10 Ne. Four types of weft yarn were used for manufacturing, including 100% cotton yarn, packaged in cones with a count of 20 Ne. Following suit is chief value cotton (CVC) yarn, a cone-shaped 60% cotton/40% polyester yarn with a count of 20 Ne. Polyester cotton blend (PC) yarn's cone-shaped 65% polyester/35% cotton blend has a count of 20 Ne. Finally, Polyester Yarn stands out for its 100% polyester composition, cone shape, and denier (D) count of 266 D or 20 Ne in cotton count. The yarn package was procured from Uttara spinning, Mirzapur, Bangladesh.

2.2 | Fabric specification

A total of four types of woven fabric with different types of filling yarns whereas warp remains the same. All the specifications are the same in the manufactured fabric sample except the type of weft yarns (100% cotton, full polyester, CVC and PC).

The specification of the fabric is $= \frac{10\times20}{56\times50}\times18''$ with a design of 3/1 Z twill. The reed count was 50's and 2 ends/dents were used for production.

2.3 | Warp yarn sizing

The process of applying a protection coating upon the yarn's surface is called sizing. In this study, the sizing operation has been performed by CCI SS600 single end sizing machine (Taiwan). The CCI SS600 single end sizing machine was designed to accommodate small quantity sizing. The machine uses basic electrical heating and a small amount of size to achieve high-quality sizing.

2.4 | Sized yarns warping

Warping was done in CCI SW550 mini warping machine (Taiwan) where 600 warp yarns were fitted on the circumference of the warping machine. The CCI warper was designed for sample looms. The machine can produce short-run warp beams with fixed lengths. The system utilizes a PC-based controller with built-in editing software for ease of usage. This function ensures the warp is wound appropriately on the drum by accurately positioning it within the width of it. Also, the SW550 Mini Warper allows for customizable tension and speed to produce high-quality warp beams.

2.5 | Drawing-in and denting

The process of inserting warp threads or ends through the heald wire is called drawing-in. The process of inserting warp threads or ends through the dents of reed is called denting. In this study, the warp threads were manually inserted into the heald wire and the reed wire with the help of a hook on the drawing-denting table. Four heald frames and the denting order was 2 ends/dent while the reed no. was 50's.

2.6 | Weaving

The CCI miniature loom (Taiwan)utilizes a PC-based controller with built-in editing software for ease of usage. According to a predetermined design, a program was set for the weaving process. The parameters that were set to the weaving machine to weave the samples for conducting the tests are illustrated in Table 1.

TABLE 1 Information about weaving of the denim samples.

Reed count	50's
Ends/dent	2
No. of heald frame used	4
Fabric structure	3/1 Z twill
Warp yarn	100% Cotton
Weft yarn	100% cotton, CVC, PC and 100% Polyester
Warp count	10 Ne
Weft count	20 Ne
EPI	56
PPI	50
Total no. of sample	04
Sample width	18 inches
Sample length	1 m each

2.7 | Experimental apparatus

Mechanical properties were assessed through a tensile strength tester (James H. Heal, England), M235 Martindale abrasion and pilling tester (China), fabric thickness gauge meter (Mitutoyo Corp., Japan), stiffness tester (SDL International, England), drape tester (James H. Heal, England), l cutter and electronic balance. All the chemicals used in the scouring and bleaching processes were procured from ABH Biochem Pvt. Ltd. The testing methods with each standard and the apparatus used for the test are listed in Table 2.

2.8 | Scouring

The scouring process commences by introducing the material, together with water, wetting agent, and sequestering agent, into a vessel at room temperature. These agents assist in the process of removing impurities and promoting the thorough penetration of chemicals during the scouring process. Following a brief 5-min immersion, sodium hydroxide (NaOH) and detergent are introduced into the solution to break down natural oils and eliminate dirt. The solution's pH is verified to ensure its efficacy. The temperature is gradually raised, and the fabric is thoroughly cleansed at a higher temperature for 45 min to eliminate impurities. After the scouring process is finished, the solution is drained to eliminate any impurities that have been loosened. Subsequently, a thorough cleansing of the fabric is achieved through a high-temperature wash with detergent. A final cold rinse removes any remaining chemicals, ensuring thorough cleanliness. Ultimately, the fabric samples are thoroughly dried and prepared for further procedures. Figure 1 depicts the total scouring process.

TABLE 2 Information about testing methods.

Test name	Test standard	Apparatus used
GSM	ASTM D3776	GSM Cutter and precision electronic balance
Pilling	ASTM D4970	Martindale abrasion and pilling tester, Photographic replica, Fabric cutter
Abrasion	ISO 12947	Martindale abrasion and pilling tester, Sample cutter, electronic weighing balance
Fabric Thickness	ASTM D5792-97	Thickness Gauge meter
Flexural rigidity	BS 3856	Shirley Stiffness Tester
Drape co-efficient	BS 5058	Cusick Drape Tester
Tensile Strength	ASTM D5035	Titan Universal Strength Tester

2.9 | Bleaching

Figure 2 depicts the bleaching procedure, the fabric is immersed in a pot containing water, wetting agent, and sequestering agent, all at room temperature. Following a short 5-min immersion, sodium hydroxide (NaOH) and a stabilizer are added, and the pH level is meticulously monitored. The temperature is then gradually raised to 60°C, and then further increased for 45 min to facilitate the bleaching reaction. The extended exposure to high temperatures and chemical substances efficiently eliminates impurities and readies the fabric for the process of bleaching. After the bleaching process is finished, the fabric is drained and then subjected to a hot wash, which includes the use of detergent to thoroughly clean the fabric. Afterward, a cold rinse is applied to eliminate any remaining chemicals and detergent. Ultimately, the fabric is thoroughly dried, resulting in a flawless condition and making it suitable for further processing.

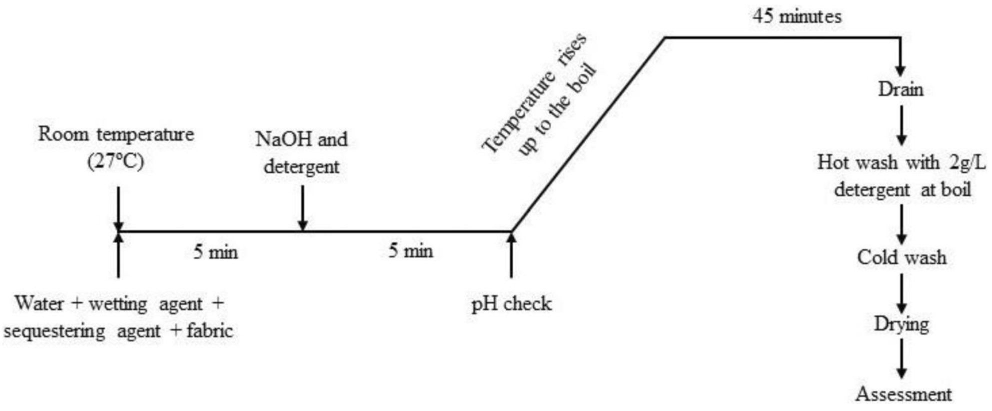

FIGURE 1 Process sequence of scouring.

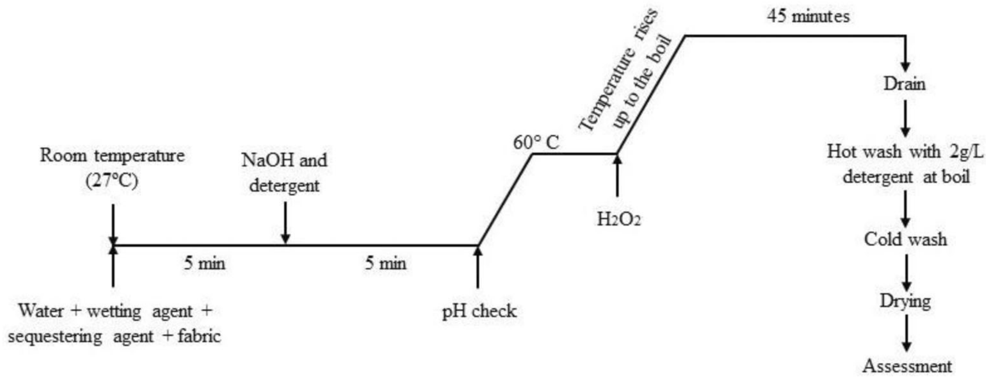

FIGURE 2 The process sequence of bleaching.

3 | RESULT AND DISCUSSION

3.1 | Effect of cotton-polyester composite yarn on fabric areal density

Figure 3 is illustrated the analysis of fabric areal density based on cotton-polyester composite yarn, it is observed that polyester fabric showed the highest areal density of 228 and cotton fabric showed the lowest areal density of 208 among between four types of fabric. The reason behind the result is that polyester is denser and heavier than cotton, whereas cotton is a more breathable and lightweight material than polyester.

Also, cotton is more porous than polyester.[17] The crystalline region of polyester fiber is higher than cotton.[18,19] With the increase of cotton in the sample, the areal density falls gradually. The cotton sample contains maximum cotton fibers which resulted in the lowest areal density among all the four samples. On the other hand, the polyester sample contains no cotton than the other three samples with the highest areal density value of 199 even after pretreatment processes among the four samples. It has been observed that when the cotton content started to reduce, the areal density increased gradually. So, it can be concluded that with the increase of polyester content in the samples the areal density increases gradually.

3.2 | Effect of cotton-polyester composite yarn on tensile strength

Analysis of tensile strength of cotton-polyester composite woven fabric is depicted in Figure 4 to explain its overall performance. The fabric's strength is an important consideration as it's important to consider that fiber properties indirectly affect fabric attributes. From the above bar diagram, it is observed that the polyester sample showed the highest tensile strength of 378.06 N in the warp direction and 371.28 N in the weft direction which is the highest breaking force among the four samples.

The cotton sample showed the lowest strength among them with 321.03 N in the warp direction and 201.9 N in the weft direction which is the lowest among all samples. The reason behind the result is that polyester is more crystalline than cotton fiber so it requires more breaking force than cotton fiber to break.[20,21] The sample containing CVC and PC in its weft direction showed almost equal strength of 304.25 and 317.47 N, respectively. CVC's strength is slightly lower than the PC sample as the PC sample has more polyester fiber than the CVC sample.

3.3 | Effect of cotton-polyester composite yarn on thickness

Figure 5 shows the analysis of fabric thickness of cotton-polyester composite woven fabric, it is observed that the cotton sample showed the highest thickness of 0.59 mm and the PC sample showed the lowest thickness of about 0.55 mm among them all. Cotton fiber has more amorphous regions than polyester fiber and for that cotton, fiber is thicker than polyester.[22,23]

So, with the increase of polyester, the thickness of the fabric should fall gradually.[24] But here it is observed an exception and that is the 100% polyester fabric sample is slightly thicker (0.55 mm) than 65% polyester containing fabric whereas the CVC fabric's thickness is 0.57 mm. Though all four fabric sample's thickness is almost equal

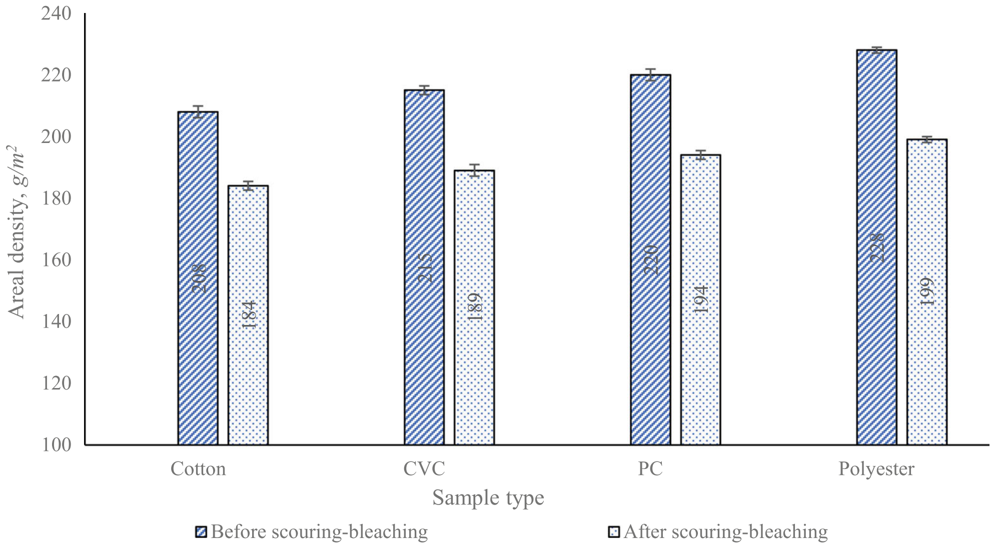

FIGURE 3 Analysis of fabric areal density based on cotton-polyester composite yarn.

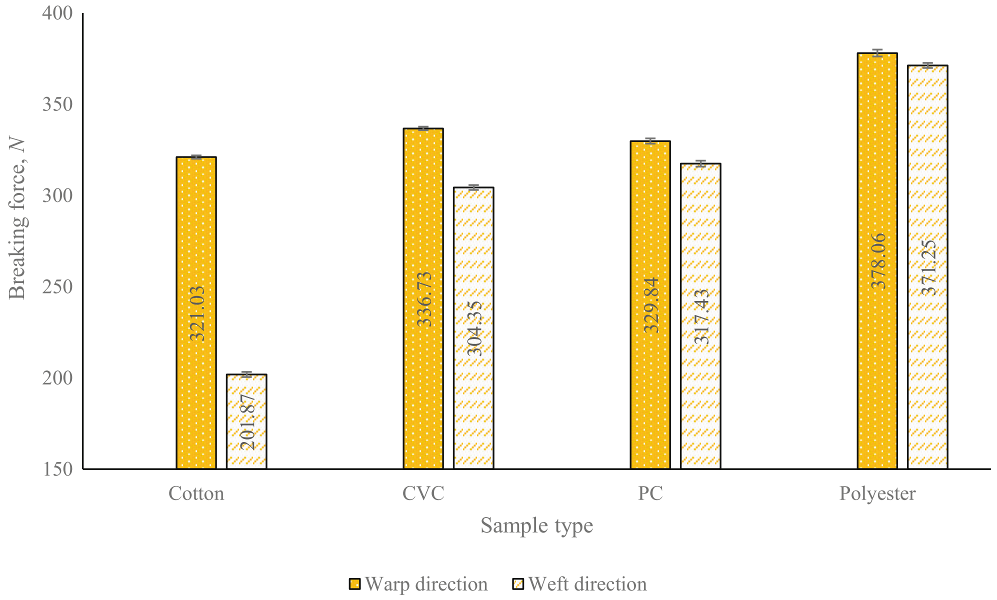

FIGURE 4 Analysis of tensile strength of cotton-polyester composite woven fabric.

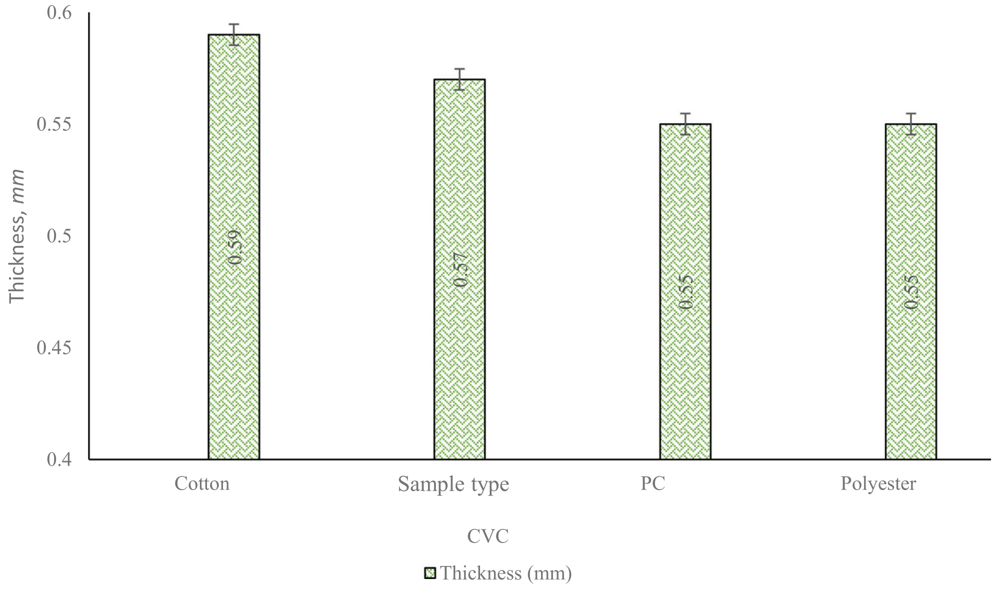

FIGURE 5 Analysis of fabric thickness of cotton-polyester composite woven fabric.

visually but precisely there is a slight difference between them and cotton showed the maximum thickness among all of them.

3.4 | Effect of cotton-polyester composite yarn on abrasion resistance

Abrasion occurs when the fabric's fibers and yarns brush against each other.[25] Abrasion involves repeatedly applying stress. As a result, abrasion resistance is equivalent to energy absorption capability. A fabric's abrasion resistance depends on fiber characteristics, yarn structure and size, fabric mass and geometry, and finish.[26] Moisture content influences abrasion resistance in hydrophilic fibers.[27] As a result, it was observed that cotton lost the most mass among all the present samples which was about 0.86% whereas polyester showed the least mass lost percentage.

Those contents that are hydrophobic in nature show less abrasion resistance than hydrophilic contents. Also, fiber structure influences abrasion resistance.[28] For example, those fibers who has less crystalline regions show greater abrasion resistance because highly crystalline fibers cannot absorb more energy than less crystalline fibers.[29,30] Figure 6 shows an analysis of fabric abrasion resistance, it is observed that the average mass loss percentage of Cotton is the lowest of all means better resistant towards abrasion 5.19% after 1000 cycles and CVC showed the lowest resistance as it showed the highest mass loss percentage (8.13%). The reason behind this is that cotton is less crystalline than polyester according to its fibrous structure.[21,31] Also, polyester is hydrophobic in nature whereas cotton is hydrophilic.[32,33]

For this reason, those samples that are cotton rich should have shown higher abrasion resistance, but in this study, it is found that the CVC sample is showing less resistance to abrasion than the PC (7.25 after 100 cycles) and polyester samples (7.63 after 1000 cycles). CVC is more cotton rich than PC and polyester but for some reason, it showed the lowest resistance to abrasion. The reason can be the fibrous structure of the polyester which is more crystalline than cotton.[34] For high crystallinity, it may be possible to take less damage through abrasion and as a result, it will show less loss in mass percentage, which may have happened in our studied sample.

3.5 | Effect of cotton-polyester composite yarn on fabric pilling behavior

A fabric's tendency to pill is correlated with its hairiness. A necessary condition that influences the formation of a pill is hairiness. Hairiness, however, is an element that is not directly controllable. Cotton's shorter fibers make it more prone to pilling than polyester.[35] Polyester, on the other hand, is naturally more resistant to pilling, making it an excellent choice for long-lasting clothing.[36] When cotton is combined with fibers such as polyester, the pilling rate varies depending on the blend and fiber ratios. For example, a cotton-polyester composite is more prone to pilling than a cotton-elastane composite because of the smoother nature of polyester fibers. Table 3 shows that the polyester sample showed the lowest pilling grade dwindling from 3–4 to 2 with the passage of cycles increased, the CVC and PC samples showed equal grades ranging from 3 to 4 and the cotton sample showed the highest grade with a little transformation after 200 cycles. The reason behind this result is that the polyester sample contains 100% polyester in weft and 100% cotton in warp. This polyester sample has more polyester fiber than the CVC and PC samples. And as we learn the greater polyester with cotton shows a greater prone to pilling, that's why the polyester sample is showing more prone to pilling than the other three samples.

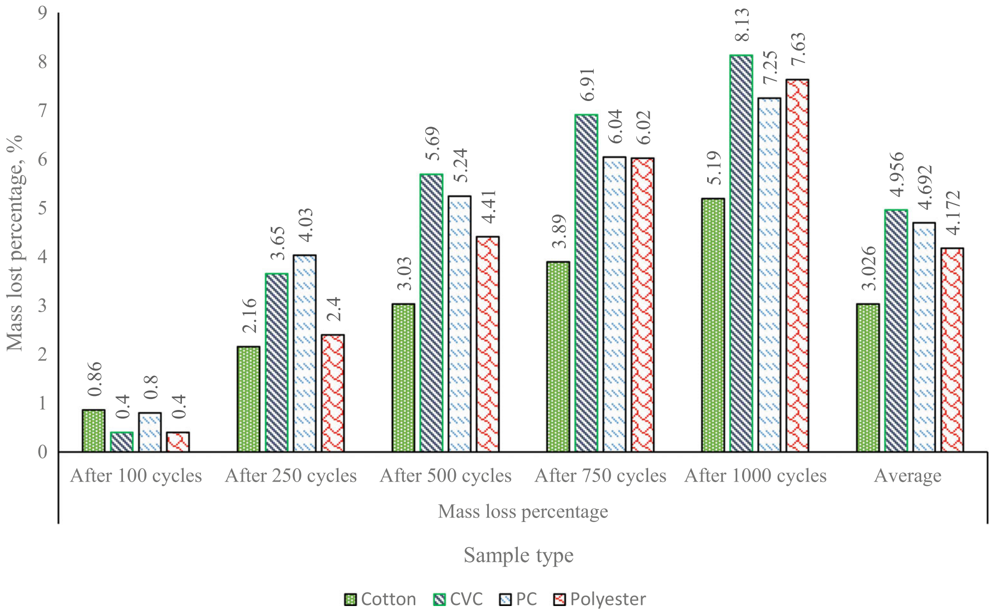

FIGURE 6 Analysis of fabric abrasion resistance.

TABLE 3 Pilling test of different fabrics.

	Pilling grade per cycle Interval				
Sample name	**After 125 cycles**	**After 500 cycles**	**After 2000 cycles**	**Average Pilling grade**	**Interpretation**
Cotton	4–5	4	3–4	4	Slight pilling
CVC	4	3–4	3	3–4	Moderate to slight pilling
PC	4	3–4	3	3–4	Moderate to slight pilling
Polyester	3–4	3	2–3	3	Moderate pilling

3.6 | Analysis of drapability effect of cotton-polyester composite woven fabric

From the bar diagram (Figure 7), it is observed that polyester fabric showed the highest drape co-efficient of 0.79% and the cotton fabric showed a lower drape co-efficient of 0.66%. Besides, the drapability of CVC and PC were 0.69% and 0.71%, respectively. The reason behind the result is that polyester is denser and heavier than cotton as explained in the areal density section. That's why polyester rich fabric showed higher drape co-efficient gradually.

3.7 | Evaluation of flexural rigidity of cotton-polyester composite woven fabric

Flexural rigidity is a property of a textile material determined by its resistance to bending in further processing and use. It is an important property regarding the esthetic and drape ability of textile materials. An increase in cotton proportion reduces bending length because the weak cohesion of fibers in cotton-rich fabrics leads them to bend more easily.[37] From Figure 8, It is observed that cotton rich fabric is less resistant to bending as the flexural rigidity is 23.33 and 4.3 μNm in warp and weft direction,

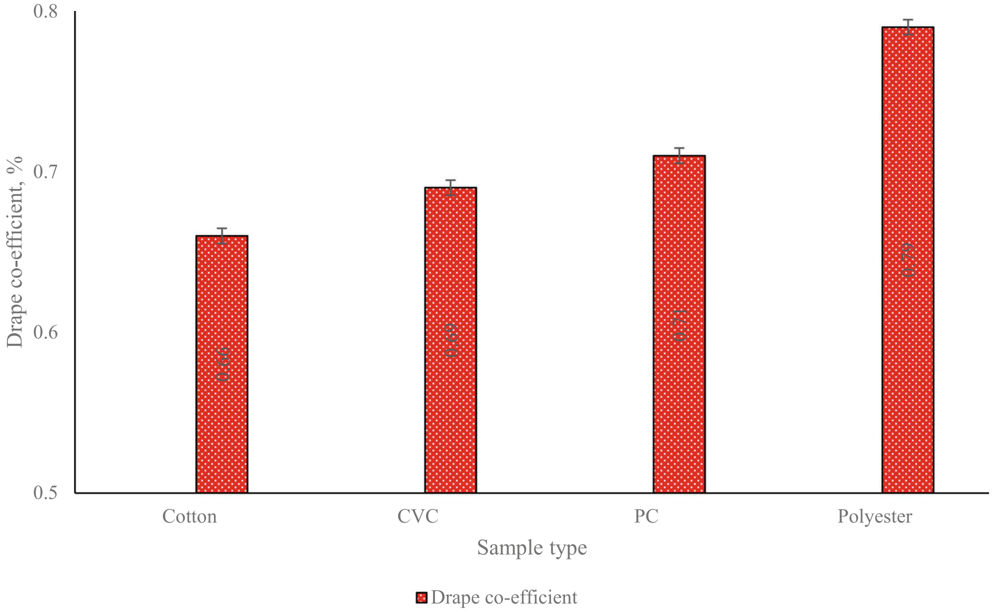

FIGURE 7 Analysis of drape coefficient % of cotton-polyester composite woven fabric.

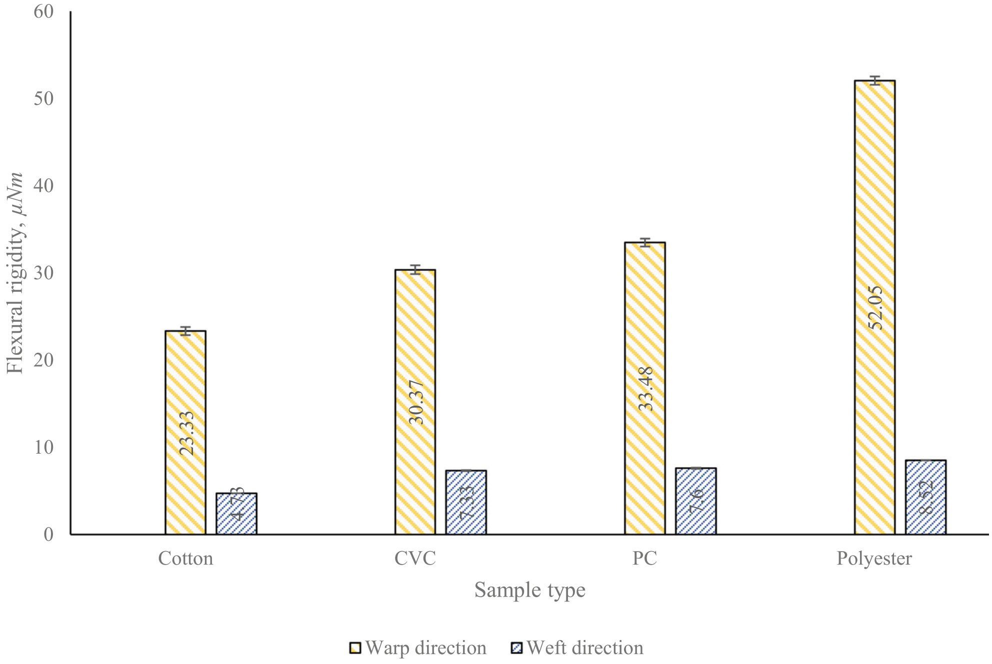

FIGURE 8 Flexural rigidity evaluation of cotton-polyester composite woven fabric.

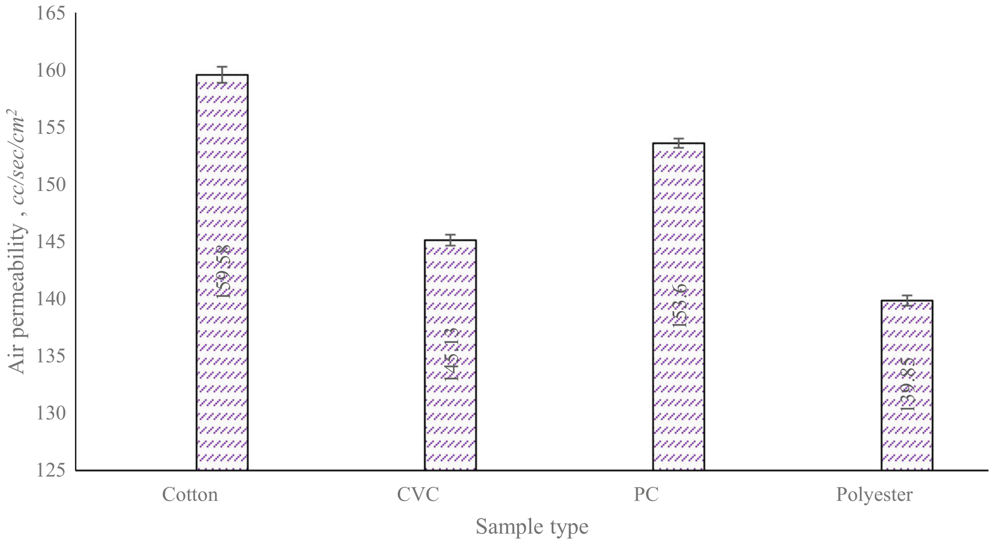

FIGURE 9 Analysis of air permeability of cotton-polyester composite woven fabric.

respectively. However, with the growing amount of polyester to the composites this nature uplifted. Finally, it is observed that 100% polyester fabric is more than twice compared to the flexural rigidity of cotton.

Therefore, their flexural rigidity shows the lowest value of them all. This polyester sample showed the highest flexural rigidity 52.05 and 8.52 μNm in warp and weft direction, respectively. The flexural rigidity of CVC and PC samples showed a moderate compared to cotton and polyester samples.

3.8 | Analysis of comfort performance of cotton-polyester composite woven fabric

The air permeability of a fabric refers to how well it allows air to move through it. Air permeability is defined as the amount of air (in milliliters) that passes through 100 mm^2 of fabric in 1 s under different pressures. The cotton fiber content in the composite increases and the fabric's thickness and weight drop.[38]

As a result, the air permeability of cotton-rich fabrics will rise. As cotton-rich fabrics get thinner and lighter in weight, air permeability increases due to less resistance to airflow. From Figure 9 which shows analysis of air permeability of cotton-polyester composite woven fabric, it is observed that the cotton sample showed the highest air permeability of 159.58 cc/s/cm^2 and polyester showed the lowest of 139.85 cc/s/cm^2.

4 | CONCLUSION

This research work aims to analyze the physico-mechanical and properties of different composite samples which were made with cotton-polyester blended yarn in the weft direction of the woven fabric in different percentages along with 100% cotton and 100% polyester. After conducting physical tests, the results showed that polyester rich fabric sample has greater strength properties than cotton rich samples in respect of areal density, strength, drape and flexural rigidity. It can be shown as 100% polyester > PC > CVC > 100% cotton. So, Apparel, sportswear, automobile upholstery, home decor, industrial settings, smart textiles, medical textiles, aerospace and defense are potential uses for fabric with enhanced mechanical qualities. The cotton rich fabric showed greater comfortability properties than the polyester rich sample with respect to air permeability, abrasion resistance and pilling resistance. It can be shown as 100% cotton > CVC > PC > 100% polyester. So, Apparel, bedding, furniture upholstery, medical textiles, sportswear, and automobile interiors are the potential many uses for fabric with improved comfort qualities, which include increased breathability, moisture wicking, softness, and overall user comfort. But the comfortability of the polyester rich fabric wasn't that bad compared to cotton rich sample. Increasing the proportion of cotton in the fabric improves breathability and comfort. On the other hand, increasing the proportion of polyester in the fabric resulted in improved strength and durability. The manufactured composites have developed the properties of both cotton and polyester as physico-mechanical and comfort properties present in the CVC and PC fabric samples, which ensures the aim of this research work.

AUTHOR CONTRIBUTIONS

Nasrin Akter, Md. Reazuddin Repon and Shaima Islam have contributed to conceptualization, methodology, data collection and original draft preparation. Arnob Dhar Pranta has contributed to resources, data analysis

and original draft preparation. Azmat Ali Khan and Amer M. Alanazi contributed to editing and reviewing. Md. Reazuddin Repon has supervised all stages of preparing the manuscript. All authors have read and agreed to the published final version of this article.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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