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Evaluating the Wear and Mechanical Properties of Cotton Fabrics for Women's Summer Clothing †

Natrayan Lakshmaiya [1], Kunnathur Periyasamy Yuvaraj [2], Seeniappan Kaliappan [3], Vinay Kumar Reddy [4] and Haleem Mohammed Ali [5,*]

[1] Department of Mechanical Engineering, Saveetha School of Engineering, SIMATS, Chennai 602107, Tamil Nadu, India; natrayanphd@gmail.com
[2] Department of Mechanical Engineering, Sri Krishna College of Engineering and Technology, Coimbatore 641008, Tamil Nadu, India
[3] Department of Mechatronics Engineering, KCG College of Technology, Karapakkam, Chennai 600097, Tamil Nadu, India
[4] Department of Mechanical Engineering, School of Engineering, SR University, Warangal 506371, Telangana, India
[5] Department of Mechanical Engineering, SRM Institute of Science and Technology-Ramapuram Campus, Chennai 600089, Tamil Nadu, India
* Correspondence: h.mohammed.24680@gmail.com
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Abstract: Recyclable yarn has become increasingly significant because of growing environmental consciousness and the necessity to acquire or enhance the qualities of woven materials in the years to come. A cotton yarn's tensile strength, rip strength, and permeability to air were examined to obtain the intended outcomes. The experiment was carried out on specimens with almost identical structures, and the impact of the weaving and various weft materials was evaluated. This endeavor aims to find the right blend or blends of regenerated fibers to substitute 100% cotton garments. The mechanical strength and physiological characteristics of Tencel textiles mixed with other regenerate cellulose yarns were compared to those of 100% cotton to attain the same or possibly superior end qualities. Thus, cotton fibers, viscosity, Tencel, modal, and hemp were used. Standard thread counts of 20 tex were used to make mixed plain woven textiles made of 100% cotton and 50:50 mixes of Tencel with other regenerating materials. The ergonomic qualities, such as air permeability, and mechanical characteristics (tension and tearing assets, pilling, abrasion resistance, and warp- and weft-wise) were assessed. It has been discovered that textiles combined with Tencel perform better than cotton ones. Consequently, it may be said that 100% cotton textiles can be replaced with a Tencel combination, using these regenerating fibers.

Keywords: tear strength; tensile properties; air permeability; cotton fiber; women summer cloth

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1. Introduction

The general standard of living is rising, as are the demands of individuals in all spheres of life and for novel or superior textiles crucial for higher levels of pleasure or use in industry. Modern fiber development must adhere to more stringent environmental criteria than in the past, and traditional synthetic fibers derived from hydrocarbons do not satisfy these standards due to their detrimental effects on the natural world. No oil is a plentiful main resource element [1]. Traditional synthetic fibers, such as polyester, polyacrylic, and polypropylene, pose a risk to the environment. The two biggest issues with synthetic polymers are their non-biodegradable and non-renewable natures [2,3]. The usage of these synthetic fibers has greatly boosted the consumption of oil since they were developed and is still going strong right now. Research suggests that polyester has surpassed linen as perhaps the most widely used fiber. As conventional (unsustainable) assets, petroleum and oil are only predicted to last for about 50–60 decades at the present level of demand. The pace at which gasoline is now consumed is said to be 100.000 times that of fossil fuel production [4]. Creating ecologically friendly renewable fibers aligns more with current ecological developments [5]. Everything a living thing can consume without endangering it is considered recyclable if it can be broken down into smaller parts (the components and chemicals) by organic decomposing organisms. It also specifies that it must be harmless and capable of quickly breaking down on a human timeframe [6]. Fibers' chemical makeup, molecular mass, and supramolecular arrangement affect their biodegradability. Although every known fiber made from natural materials is biodegradable, there are several drawbacks to their development and manufacturing methods. Large volumes of insecticides are applied during the growth of cotton and various agricultural fibers, harming the ecosystem [7].

Krook and Fox initiated the research on ripping power. "Del" is the name they gave to the triangle deformation at the tearing's operating zone. According to them, the structure of the fabric is more significant as it establishes the tear location's unique form and significantly impacts the material's rip resistance. Crosswise fibers pull away from the weave and grow del fibers at the start of a mouth tear to evaluate when the stresses on the tails are first used [8,9]. The crimped material is removed from the two groups of yarns close next to the del, and crimped trade takes place within the untorn textiles; the untorn textiles before the del grow stuffed in the plane of damage. The length of the del yarn and its consequent high tearing durability correlate with the ease with which the cross yarns separate from the remainder of the fabric [10]. Furthermore, it has been discovered that a specimen's mean tear resistance will rise if the density of longitudinal threads is reduced (keeping the total number of crosswise yarns unchanged). Conversely, if the weight of the crosswise network of yarns is changed (keeping the total number of lengthwise threads unchanged), the observed ripping force is not significantly affected [11]. Additionally, it was claimed that employing yarns with a greater tensile strength or utilizing lengthier floats or additional slick yarn would boost the resistance to tears by reducing contact in the material itself. Hager investigated the tear strength as well. The starting quantities of a fabric's breakage strength and extension at breakdown in both weft and warp orientations can be affected by various direct and indirect variables. The impact of a fabric's constructional characteristics, including its weave, bend, and woof string weight, is significantly lower. Other variables, like the environment where spinning occurs, could indirectly affect the ultimate values [12].

The utilization of Tencel fibers in combination with different cellulose mixtures (50:50) to substitute 100% cotton fabric remains the subject of this research due to Tencel's superior mechanical and comfort attributes, resulting from the water present in its crystalline form. No information has been released about using regenerating mixtures to enhance their qualities. The present research has investigated and provided data on mechanical and comfort qualities.

2. Materials and Methods

2.1. Materials

A combination of cotton and rejuvenating fibers, including hemp, viscose, modal, and Tencel, was employed during this endeavor. The specific composition of each fiber utilized in this research is outlined as follows: hemp 50:50, viscose 50:50, modal 50:50, and cotton 100 in Tencel.

2.2. Experimental methods

2.2.1. Yarn production

Table 1 shows the ratios used to make cotton mixed yarns of 24 tex. The materials were blended in a blow chamber to create yarns using the ring spinning technique. Here, 120 gsm flat-woven fabrics with 76 × 68 structures per square inch were created on a

Taiwanese-made CCI loom (model SL 8900S). The weaving machine produced 36 picks per minute with a reed count of 35. There were 1120 warp ends in all. After the sample textiles were desized, they were cleaned and disinfected.

Table 1. Cotton fabric technical specifications.

Fabrics	Warp Ne	Weft Ne	Ends per Inch	Picks per Inch
F1	60	60	60	50
F2	60	60	60	60
F3	60	60	70	60
F4	60	60	70	70
F5	60	60	80	70
F6	60	60	80	80
F7	60	50	60	50
F8	60	50	60	60
F9	60	50	70	60
F10	60	50	70	70
F11	60	50	80	70
F12	60	50	80	80
F13	40	40	60	50
F14	40	40	60	60
F15	40	40	70	60
F16	40	40	70	70
F17	40	40	80	70
F18	40	40	80	80
F19	40	30	60	50
F20	40	30	60	60
F21	40	30	70	60
F22	40	30	70	70
F23	40	30	80	70
F24	40	30	80	80

2.2.2. Air Permeability Testing

The assessment of material permeability to air involved the utilization of an air penetration tester, specifically the FX3300 model.

This testing apparatus applied an experimental pressure reduction of 100 Pascal within a defined test area of 20 square centimeters. The evaluation process adhered to the guidelines outlined in ASTM D737-04, with updates from the 2018 standard revision. Five individual measurements were taken using the prescribed methodology to conduct the test, and the resulting data were subjected to statistical analysis. The mean (average) of these five measurements was then calculated and published. This comprehensive approach ensured a thorough and reliable assessment of the fabric's air permeability characteristics, providing valuable insights into its performance according to the established testing standards. Figure 1 shows photographic images of the air permeability tester.

Figure 1. Photographic image of air permeability tester.

2.2.3. Mechanical Characterization

Determining the material's tensile strength at its maximum point involved using a yarn tension tester, a specialized instrument designed for assessing the strength properties of yarns and fabrics. This testing procedure adhered to the standards outlined in ASTM D5035 for both warp and weft tensile testing and ASTM D2256 for yarn tensile strength assessment. To measure the tensile strength along the warp and weft directions, the fabric underwent testing according to the prescribed procedures of ASTM D5035, which specifically addresses the tensile properties of textiles. Additionally, the yarn tensile strength was assessed using the methodology stipulated in ASTM D2256, a standard that focuses on determining yarns' breaking force and elongation. For an evaluation of the fabric's rip strength along the warp and weft directions, ASTM standard D1424-09 (2013) was employed. This standard provides guidelines for conducting a grab test, allowing the measurement of the force required to tear the fabric. Adhering to these established testing standards resulted in a comprehensive and accurate assessment of the material's tensile and rip strength properties, providing valuable insights into its structural integrity and performance characteristics. Figure 2a,b show the photographic images of yarn tensile and wear testing.

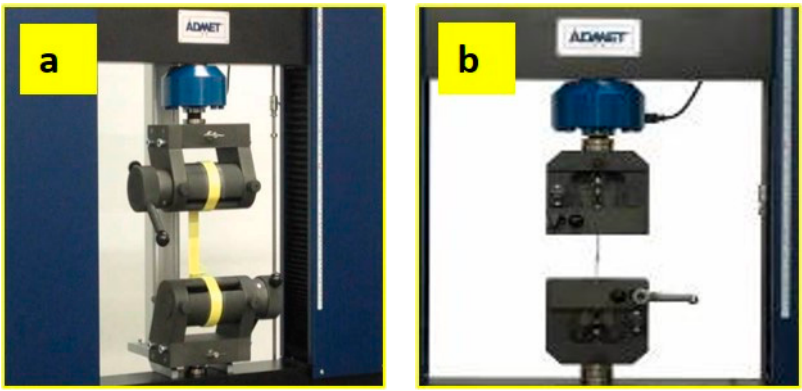

Figure 2. (**a**,**b**) show the photographic images of yarn tensile and wear testing.

3. Result and Discussion

3.1. Air Permeability

The type of dietary fiber, skein flexion, skein longitudinal weight, and thread microstructure all impact the capacity of a woven fabric to absorb air. Increasing yarn twist causes a reduction in yarn dimension as well as covering aspect, which raises air permeability. A higher twist rate of the yarn can also result in a more circular thread, which increases the fabric's air permeability. Higher-density textiles have less air permeability because the threads are tightly enclosed in a tight interwoven framework. The intra-yarn gaps are impacted by the yarn's cross-sectional area, which also impacts the material's permeability [13]. Table 2 shows that the maximum air permeability of the Tencel/modal material is 610 mm/s. The yarn weave of multimodal and Tencel has channels that enhance the permeability of the cloth. Tencel/viscose and Tencel/hemp are more porous than cotton (362 mm/s) due to their air permeabilities of 528 and 501 mm/s, respectively.

Tencel/ viscose has a higher air permeability than Tencel/hemp, maybe because of the yarn's increased regularity (IPI = 20.5). Because the fiber made from cotton is coarser (1.52 dtex) than the other fibers (1.4 dtex), cotton fabric has smaller intra-yarn gaps and less air permeability. Additionally, yarns made of cotton have a higher irregularity index (IPI = 141), which might result in increased resistance to wind and decreased air circulation. Figure 3 shows the impermeability conditions of 24 types of cotton samples [14].

Table 2. Comparison of mechanical and tear strength of different materials.

Testing	Tensile Strength (kgf)		Tear Strength (gf)		Air Permeability
Conditions	warp	weft	warp	weft	mm/sec
Cotton	25	21	1150	1156	396
Tencel/Modal	33	24	1325	1232	620
Tencel/Viscose	22	23	1562	1428	536
Tencel/Hemp	26	25	1684	1201	529

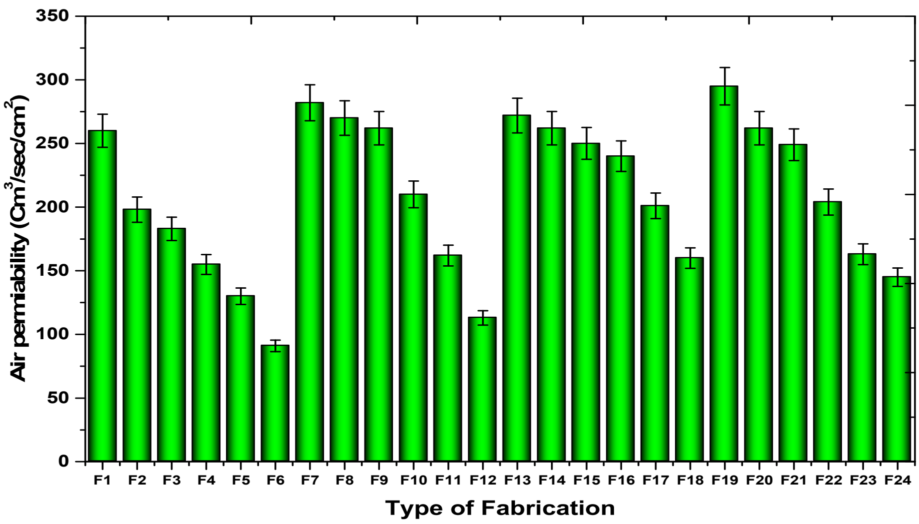

Figure 3. The impermeability conditions of 24 types of cotton samples.

3.2. Mechanical Properties of Yarn

Figure 4 shows an illustration of the weaved cotton textiles' tensile strengths. A comparison of tensile and tear strength of different fabric yarn with cotton was revealed in Table 2. Regarding Tencel, when compared to other textiles, modal fabric has a greater tensile strength (28 kgf) when seen as both weft and warp. The tensile strength mostly depends on the yarn and fiber durability, which is why Tencel multimodal yarn has a greater strength [15]. Tencel/viscose and Tencel/hemp textiles had tensile strengths of 28 and 23 kgf, respectively, when looking at the warp-wise orientation. Nevertheless, cotton textiles had a tensile force of 26 kgf, a value comparable to Tencel/viscose since their yarns had the same toughness. Figure 4 illustrates how the situations resemble one another in the weft-wise orientation. The durability and flexibility of the yarn inside the material's pattern determine the tear toughness [16]. The yarn's twist, dietary fiber, and cleanliness all have an additional influence on its movement. The identical fabric texture had no bearing on this project [17].

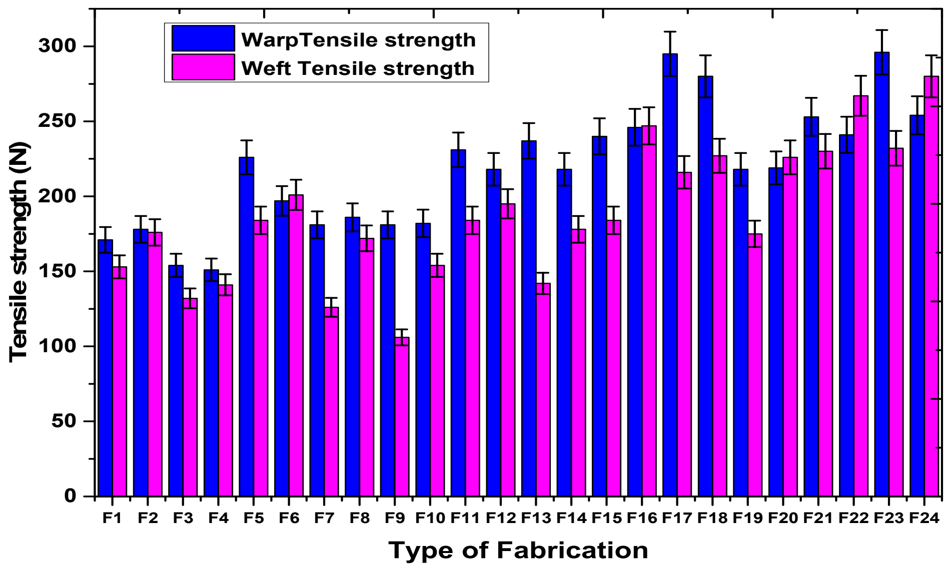

Figure 4. The tensile strength of 24 types of cotton samples.

Figure 5 shows that the Tencel/modal material has a greater tear resistance across the warp and weft orientations due to stronger Tencel/modal yarns. Since cotton yarns had shorter fibers (27 mm), they received a greater twist than yarn made of other materials [18].

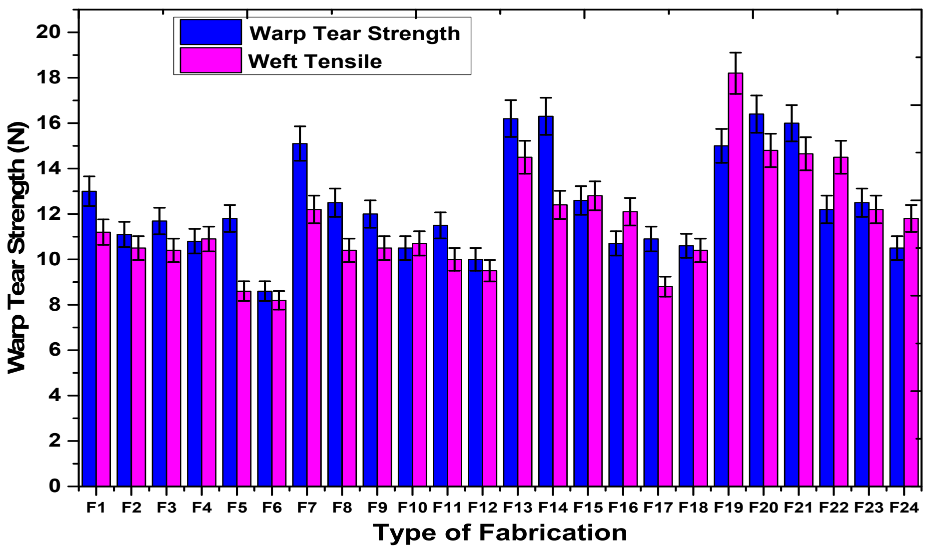

Figure 5. The tear strength of 24 types of cotton samples.

As a result, the fabric made from cotton has the lowest tear resistance in both the weft and warp orientations due to the yarn's increased twisting and inconsistencies, which make it less durable, stiff, and clean (IPI = 141). Tencel/viscose yarn (IPI = 29.6) is finer than Tencel/hemp yarn (IPI = 52.4); therefore, yarn in Tencel/viscose textiles may have superior movement. Tencel is a rayon that has greater tear resistance than hemp, even though the fibers have the same stiffness and twisting [19]. The outermost flaw in cloth, known as pilling, results from yarn slipping or fiber displacement brought on by wearing and friction. Fuzz creation, entanglement development, and wear-off are the four stages of pilling. Fuzzy and blister development impacts the fabric's surface, which impacts a material's longevity, appearance, and customer acceptability. Comparably, pressing one material surface against another causes abrasion, which damages the filaments, yarn, and clothing. While Tencel/modal, Tencel/viscose, and Tencel/hemp exhibit lesser release and greater durability against abrasion than other mixes, linen exhibits more pillaging and poorer durability against wear. Resistance to abrasion and pillaging depends on several variables, including the kind of cellulose, the fiber's intrinsic mechanical characteristics, the dimensions of the fiber's framework, and the material's composition and thickness. Since cotton yarns have a shorter expansion at the breakdown and a higher risk of separation, as well as a lesser capacity to tolerate frequent deformation, they provide less defense against abrasion and pilling. As a result, cotton offers greater pillaging and poorer durability against abrasion.

4. Conclusions

Tencel, modal, viscose, and hemp were combined with a fabric made from 100% cotton in this garment. A study and comparison were performed on the mechanical and ergonomic features. Of all the mixes under study, it was discovered that the Tencel/modal mixed material had the best mechanical (tensile and tear strength) and physiological (air permeability) characteristics. Furthermore, compared to 100% cotton, Tencel/viscose and Tencel/hemp had superior mechanical and comfort qualities. Therefore, textiles made of Tencel mixed with modal, viscose, and hemp are preferable to more environmentally harmful fabrics made of pure cotton. Therefore, Tencel, combined with other regenerating textiles, may substitute garments constructed from pure cotton, offering better features in terms of convenience and mechanical characteristics.

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