

**Project title:** In vitro evaluation and understanding of fabrics interaction with skin cells and dominant skin microbiome: a concurrent material degradation

**Industry partner(s):** Lululemon Inc.

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**Introduction & Background:**

Fabric performance under simulated skin interactions, particularly sweat exposure, critically affects comfort, durability, and functionality in clothing applications [1,2]. Users engaged in physically demanding activities rely on fabrics designed to maintain mechanical integrity despite prolonged moisture exposure, which can significantly degrade fiber structures and mechanical properties [2,3]. However, comprehensive data on how sweat influences tensile strength, elasticity, stiffness, and overall durability across diverse fabric types remain limited [3,4]. This research investigated the hypothesis that artificial sweat significantly impacts the mechanical characteristics, such as maximum load, tensile strength, elastic modulus, and deformation energy, of common textile fabrics. Standardized tensile tests (ASTM D5035) were conducted on various fabric compositions and structures. Findings from this study provide manufacturers with essential insights to optimize fabric selection, thus improving material longevity, comfort, and sustainability by addressing moisture-induced degradation.

**Relevance to Circular Economy:**

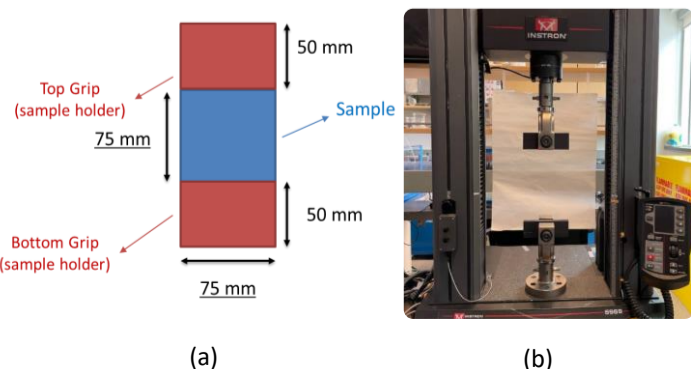
The textile industry faces significant circularity challenges due to high material turnover, intensive resource consumption, and limited recycling options [4]. Continuous exposure to bodily fluids, such as sweat, accelerates fabric degradation, shortening garment lifespan and increasing textile waste. By investigating how artificial sweat influences fabric durability and mechanical integrity, this research directly contributes to informed fabric selection and design optimization. Consequently, enhanced fabric longevity reduces textile waste, supports strategies for improved recycling or downcycling, and ultimately promotes a more sustainable, circular textile economy.

**Methodology:**

Mechanical testing was conducted on nine fabric samples categorized into natural, semi-synthetic, and synthetic fiber types to evaluate the influence of artificial sweat exposure on their tensile performance. Specimens measuring 175 mm x 75 mm were prepared and tested according to the standardized ASTM D5035 method, utilizing an Instron 5969 universal testing machine. Tests were performed at a deformation speed of 150 mm/min, ensuring consistency across trials. Each fabric was subjected to three test conditions: dry (control), immersed in artificial sweat (AS), and immersed in water, with each condition replicated three times to establish statistical reliability. Artificial sweat formulation closely mimicked human sweat, containing key constituents such as hydrolyzed fatty acids, amino acids, cholesterol, squalene, and mineral salts, adjusted to a physiologically relevant pH of 6.5. Fabric specimens were incubated in artificial sweat at 37°C for 24 hours, simulating realistic exposure. Measured mechanical properties included maximum load (N), ultimate tensile strength (MPa), elastic modulus (MPa), deformation energy (MJ/m<sup>3</sup>), and extension at maximum load (mm). Comparative statistical analysis focused on evaluating relative performance changes across testing conditions, identifying potential material degradation patterns relevant to practical clothing applications.

**Table 1:** Summary of NBR-NGP blends, used for downstream testing.

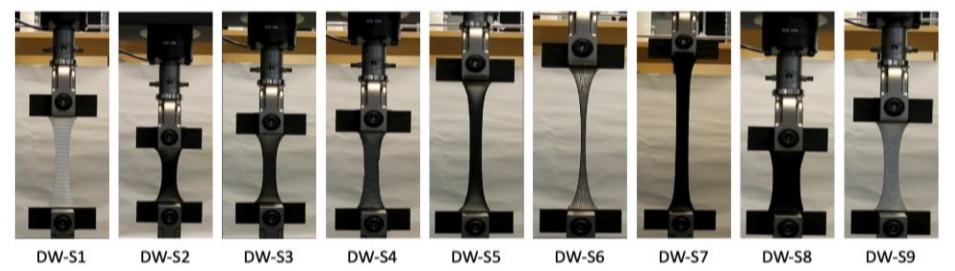
Code	Fiber Composition	Fabric Structure
S-1	Nylon/Polyester/Elastane	Weft Knitted Double Jersey
S-2	Pima cotton/Lycra elastane	Weft Knitted Single Jersey
S-3	Pima cotton/Nylon/Lyocell/Elastane	Weft Knitted Double Jersey
S-4	Merino wool	Weft Knitted Double Jersey
S-5	Nylon/Xtra Life Lycra elastane	Warp Knitted Tricot
S-6	Polyester/Nylon/Lycra elastane	Weft Knitted Double Jersey
S-7	Nylon/Lycra elastane	Weft Knitted Interlock
S-8	Polyester	Warp Knitted Tricot
S-9	Modal/Alginate/Nylon/Elastane	Weft Knitted Single Jersey



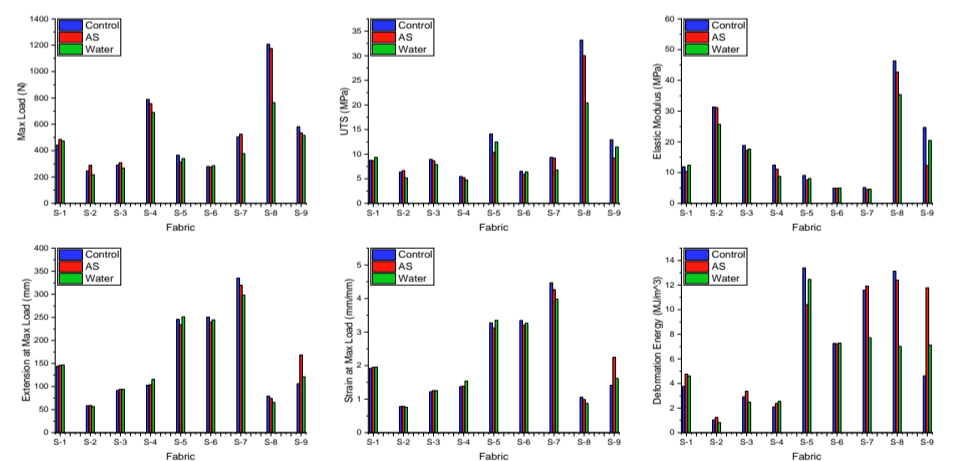
**Figure 1:** (a) Schematic representation of the tensile test sample and gripping arrangement, and (b) experimental tensile testing setup using an Instron 5969 universal testing machine.

**Results & Discussion:**

The mechanical performance of the tested fabric samples exhibited distinct variations based on fiber composition and exposure conditions. Synthetic fabrics, particularly those composed predominantly of polyester (S-8), demonstrated superior mechanical properties. For instance, fabric S-8 exhibited the highest ultimate tensile strength (~33 MPa), maximum load (~1200 N), and elastic modulus (~46 MPa), indicating outstanding resistance to tensile stress and deformation. Conversely, natural fabrics such as merino wool (S-4) and cotton blends (S-2) demonstrated significantly lower strength and stiffness, with tensile strengths of approximately 5 MPa and 7 MPa, respectively. Exposure to artificial sweat (AS) notably affected fabric behavior, supporting the initial hypothesis that sweat exposure influences mechanical integrity. Most fabrics exhibited reduced strength and elasticity after AS exposure, likely due to structural alterations or fiber weakening from sweat constituents. Notably, fabrics S-5 and S-8 showed the most significant reductions (~10–15%) in ultimate tensile strength and deformation energy after AS exposure, emphasizing that high-performance synthetic fibers are also susceptible to degradation in realistic wearing conditions. Interestingly, a subset of fabrics (S-1, S-2, and S-3) displayed slight increases in maximum load post-AS exposure, potentially resulting from fiber swelling or temporary stiffening effects due to moisture absorption. This unexpected result underscores the complexity of fiber-fluid interactions and suggests further microscopic analysis could yield valuable insights into internal structural changes. From an industrial perspective, these results highlight crucial considerations for fabric selection in applications demanding sustained mechanical performance under repeated moisture exposure, such as sportswear or outdoor apparel. Synthetic fabrics provide superior initial mechanical characteristics; however, their susceptibility to performance loss over prolonged use requires manufacturers to balance mechanical robustness with comfort and longevity.



**Figure 2:** Fabric samples (S1-S9) at maximum elongation after distilled water exposure.



**Figure 3:** Mechanical properties comparison for fabrics under Control, Artificial Sweat (AS), and Distilled Water (DW) exposure.

**Conclusion & Next Steps**

This study confirmed that exposure to artificial sweat notably influences fabric mechanical properties, with synthetic fabrics demonstrating higher initial performance but also sensitivity to degradation upon sweat exposure. Next steps include detailed microscopic examinations (SEM analysis) to better understand fiber-level degradation mechanisms and exploring additional protective treatments or fiber blends to enhance moisture resilience and prolong fabric lifespan.

**References:**

- Pasayev, N. (2017). Investigation influence of human sweat and moisture on the resistance to abrasion of woolen fabrics. *J Textile Eng Fashion Technol*, 2(1), 257-259. DOI: 10.15406/jteft.2017.02.00042.
- Cardamone, J. M., & Turner, S. (1990). Effect of perspiration on the fine structure of cotton fabrics. *Textile Research Journal*, 60(4), 209-215. DOI: 10.1177/004051759006000408.
- Rahman, M., Liu, W., & Wang, X. (2024). Effect of sweat pH on moisture management and mechanical properties of cotton fabrics. *International Journal of Fashion Design, Technology and Education*. DOI: 10.1080/17543266.2024.2347299.
- Sule, A. D., & Bardhan, M. K. (2023). Engineering comfort in sports textiles: A critical review. *Textiles*, 3(3), 411-435. DOI: 10.3390/textiles3030022.