international DESIGN JOURNAL
Print ISSN 2090-9632
Online ISSN 2090-9640

# Enhancing the Comfort Properties of Headscarf Fabrics for Chemotherapy Patients Using Phase Change Materials

**Hafez S. Hawas**
Spinning and Weaving Dept., Faculty of Applied Arts, Helwan University, Giza, Egypt
Faculty of Energy and Industrial Technology, October Technological University, Giza, Egypt
**Eman Zaher Goda**
Spinning and Weaving Dept., Faculty of Applied Arts, Helwan University, Giza, Egypt

## Abstract

Hair loss (Alopecia) caused by chemotherapy is a prevalent and distressing side effect that many cancer patients experience. It can cause psychological problems including poor self-esteem and social withdrawal. Chemotherapy can also interfere with the body's natural ability to regulate its temperature, leading to uncomfortable physical sensations of extreme heat or cold. The main objective of this research is to create head covering materials that use Phase Change Materials (PCMs) to reduce these symptoms. These PCM-based textiles are designed to improve patient comfort and well-being during chemotherapy by preserving an even and comfortable temperature around the scalp. Four samples were produced using three weft materials blended as following; (50 % Viscose PCM: 50 % Lyocell, and 50 % Viscose PCM: 50 % Bamboo), using two weave structures (Matt Rib 2/2 and Piqué), then the laboratory tests were applied to assess comfort and heat capacity properties for the produced samples. Fabric Air Permeability, Stiffness, Horizontal Wicking, Water Vapor Permeability, Differential scanning calorimetry (DSC) and the porosity percentage of the fabrics were all assessed. Results revealed that Piqué weave enhances air permeability and reduces fabric stiffness, with Bamboo weft achieving the highest air flow and lowest stiffness. Lyocell excels in moisture vapor transport, horizontal wicking, and latent heat properties. Matt Rib weave improves horizontal wicking and latent heat, with fabric weight directly affecting heat capacity.

## Keywords

Chemotherapy, Alopecia (hair loss), Medical textile, Comfort properties, phase change materials (PCMs), Latent heat.

**Paper received December 22, 2024, Accepted February 7, 2025, Published on line May 1, 2025**

## 1. Introduction

Technical textiles encompass textile-based products with performance and functional characteristics rather than decorative or aesthetic purposes. [1], [2], [3], [4] Nonetheless, its distribution patterns are similar to those of home textiles in general. The primary distinction is that, although the activities in clothing textiles are uniform in nature, technical textiles encompass a diverse variety of groups, ranging from the manufacturing of parachutes to golf clubs makers. [5] Technical textiles can be classified into twelve sectors according to the market as follows: buildtech (construction), sportech (sports), oekotech (ecological protection), indutech (industrial), agrotech (agriculture), medtech (medical), geotech (geotechnical), hometech (domestic), clothtech (clothing), protech (protective), packtech (packaging), and mobiltech (transportation). [6], [7]

Medtech or medical textiles -also known as healthcare textiles- are one of the more continual expanding sectors within the market of technical textile. [8], [9], [10] They comprise a broad range of items, and their products are primarily produced using four different kinds of textile structures. They can be knitted, woven, braided, or nonwoven. While the fourth of them can be manufactured straight from fibers or even polymers, the first three items are made from yarns. The main characteristics of textile materials used in medicine include softness, flexibility, tenacity, absorbency, and biodegradability or biostability. The aforementioned specifications can be satisfied by employing appropriate polymers in the manufacturing of textile fibers and materials. [2] Medical textiles can be implantable or non-implantable , the implantable textile materials are used for replacement of the damaged tissues or

CITATION
Hafez Hawas, Eman Goda (2025), Enhancing the Comfort Properties of Headscarf Fabrics for Chemotherapy Patients Using Phase Change Materials, International Design Journal, Vol. 15 No. 3, (May 2025) pp 37-47

organs in the body, on the other hand, the non-implantable textile are meant to be applied externally, sometimes in contact with the skin and other times not. [9],[11], [12]

A substantial class of the intelligent materials of medical or healthcare textiles are PCMs or phase changing materials; as their morphology (such as molecular structure, shape, solubility, porosity, state) is changed as a response to predetermined stimuli (such as chemical, thermal,..) [13]. Phase changing materials are compounds that have a distinctive ability to release, absorb and store temperature -through chemical bonds change- during state shift (such as from solid to liquid, or from liquid to solid). [14], [15], [16]

As latent heat storage is considered one of the best methods for storing thermal energy, PCMs -due to their higher latent heat values- offer a higher storage density and require only a small temperature difference for storing and releasing heat. They can absorb and release significant amounts of heat energy during their phase transitions, such as melting and solidifying. [17], [18], [19] PCMs possess several outstanding characteristics; they are nontoxic, highly chemically stabile, noncorrosive, biocompatible, and nonexplosive. They exhibit excellent chemical properties which allowing them to complete reversible freezing and melting cycles without degradation even after long term thermal cycling. [18], [20]

PCMs can be embedded into textiles to create a material that combines both the benefits of PCM with the advantages of textile materials. Textiles are lightweight, comfortable , portable , and practical which makes them ideal for such applications. [21] Various processes such as bi-component synthetic fiber extrusion, coating, laminating, melt spinning, encapsulation, and finishing can be used to incorporate PCMs into textile materials. [22], [23]

When in contact with the human body, clothing should be comfortable for extended wear and free from issues like blood flow restriction, skin irritation, or other health problems. PCMs are ideal compounds for achieving this, as they help maintain the body in a comfortable and normal temperature range. [20], [24]

There are countless applications of PCMs in the medical field, for example, heat and cold therapy (e.g., blankets to prevent hypothermia and cooling packs for post-surgery use), neonatal care (e.g., maintaining suitable ambient temperatures for newborns, which is critical to prevent conditions like neonatal asphyxia), orthoses and prostheses (e.g., enhancing wearing comfort), and storage and transport (e.g., temperature regulation during cancer drug delivery), and many other use fields for PCMs in medical applications. [25], [26], [27]

One of the most significant areas of medical concern is cancer. In 2020, approximately 19.3 million new cases of cancer were recorded globally, making it one of the primary causes of death worldwide. The three major clinical therapies for cancer are chemotherapy, radiation therapy, and surgery [26], [28], [29], [30]

Chemotherapy, in particular, aims to eradicate cancer cells by targeting rapidly dividing cells. However, conventional chemotherapy also affects healthy cells that divide quickly, leading to side effects such as fatigue, infections from damaged blood cells, and hair loss caused by damage to hair follicle cells. [31], [32], [33], [34]

One frequent and upsetting side effect of chemotherapy is alopecia (or hair loss). Alopecia, brought on by chemotherapy, is commonly cited as the most upsetting side effect of the cancer treatment. It can result in psychological problems including social disengagement, low body image, and even resistance to potentially healing treatment. All the body areas are influenced by chemotherapy-induced alopecia, including the pubic hair, beard, eyebrows, and eyelashes, however the scalp has the most noticeable hair loss. One to three weeks after beginning chemotherapy, patients begin to experience headaches, discomfort, and irritation before their scalps begin to lose hair. [35], [36], [37]

In addition to alopecia, chemotherapy patients often experience disruptions in their body’s natural temperature regulation. Extreme hot or cold feelings result from this, and periods of shivering or perspiration make the physical pain worse. The scalp is more susceptible to these temperature changes since it is more exposed as a result of hair loss. [38], [39], [40], [41],

By preserving a constant and comfortable temperature around the scalp, PCM-based textiles can aid in dealing with these issues. PCM materials can relieve sudden changes in temperature by absorbing, storing, and releasing heat as needed, which help in improving chemotherapy patients' comfort and general well-being.

## II. Materials and Methods

This experimental work is focus on studying the effect of different weave structures and weft materials on the comfort properties of produced headscarves fabrics as air permeability, Moisture Vapor Transport Rate (MVTR), stiffness, horizontal wicking, and latent heat.

### 2.1. Warp & Weft Materials

Four samples were produced, using ITEMA dobby weaving machine with the specifications as shown in Table (1).

Table (1) Specifications of Produced Samples

| Sample No. | Fabric structure | Warp material | Warp count (Ne) | Ends/ inch (EPI | Weft materials | Ratio | Weft count (Ne) | Picks /inch (PPI) | Mass per unit area (g/m2) | Thickness (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| S1 | Matt Rib 2/2 | Cotton | 50/2 | 91 | Viscose PCMs: Lyocell | 50%:50% | 30/1 | 61 | 136.2 | 0.30 |
| S2 | | | | | Viscose PCMs: Bamboo | | | | 127.6 | 0.35 |
| S3 | Bique | | | | Viscose PCMs: Lyocell | | | | 132.4 | 0.37 |
| S4 | | | | | Viscose PCMs: Bamboo | | | | 126.6 | 0.42 |

Figure (1) indicates 3-D simulation of weave structure modeled in TexGen software; (A) Matt Rib 2/2 and (B) Piqué, while Figure (2) shows macroscopic images of the produced headscarf fabric in grayscale mode.


(a) (b)

Figure (1) 3-D Simulation of (A) Matt Rib 2/2 and (B) Bique Weave Structure Modeled in TexGen

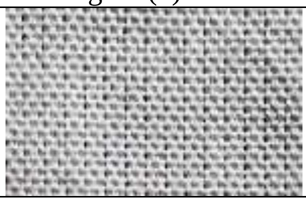
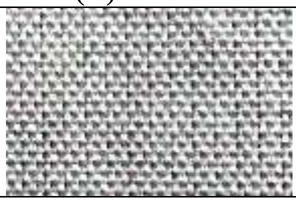
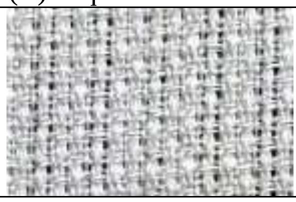
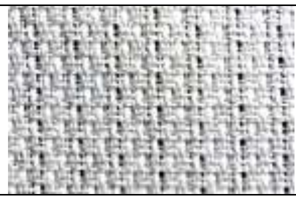
|  |  |  |  |
|---|---|---|---|
| Sample 1<br>50% Viscose pcm : 50% Lyocell ( Matt Rib) | Sample 2<br>50% Viscose pcm : 50% Bamboo ( Matt Rib) | Sample 3<br>50% Viscose pcm : 50% Lyocell ( Piqué) | Sample 4<br>50% Viscose pcm : 50% Bamboo ( Piqué) |

Figure (2) Macroscopic Images of the Produced Headscarf Fabric in Grayscale Mode

Figure (3) illustrated 3-D presentation for research sample no. 4 (50% Viscose pcm : 50% Bamboo with Piqué weave structure).

Figure (3) 3-D Presentation for Research Sample No. 4

### 2.2. Characterizations

Five comfort testing were carried on samples to evaluate its performance according to standard test methods and end use. Air permeability was conducted according to ("ASTM D737 -04), Stiffness of samples were evaluated according to ("ASTM D4032 ),Horizontal wicking was examined according to (AATCC 198 (2012)), Water vapour permeability was tested using dish method according to ( BS 7209.) and Differential scanning calorimetry (DSC) was conducted according to (ASTM E793 (2001)).

The porosity percentage of the fabrics was assessed using a digital image analysis technique. Images were captured with a mobile magnifier application. These fabric images were initially saved in grayscale and then converted to black-and-white monochromatic images using Adobe Photoshop. Following this, the Nedgraphics program was used to analyze the images and determine the porosity percentage by calculating the ratio of each color pixel.

## III. Result and Discussion

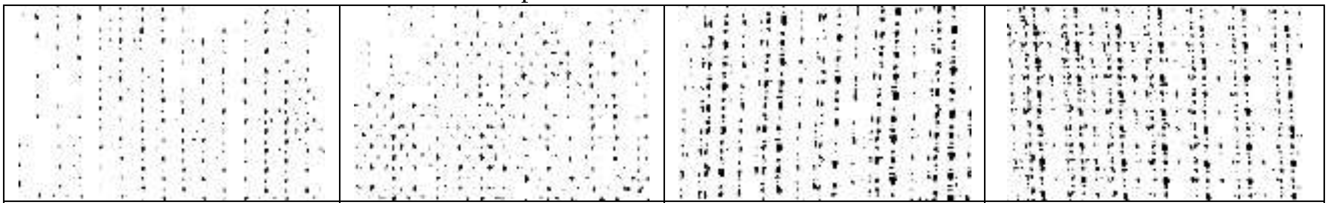
The main objective of This part is studying the effect of the research parameters on the produced samples properties. The following Table (2) shows the results of tests applied to the produced fabrics.

Table (2) Produced Fabrics Testing Results

| Sample No. | Variables | | Results | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Fabric structure** | **Weft materials** | **Air Permeability (Cm3/Cm2/S)** | **Moisture Vapor Transport Rate (g / m2 / day)** | **Stiffness (Gf)** | **Horizontal Wicking (mm/sec.)** | **Latent Heat (j/g)** | **Thermal Capacity (j/m2)** |
| S1 | Matt Rib 2/2 | 50%Viscose PCMs: 50% Lyocell | 103.7 | 702.7 | 104 | 12.66 | 9.2 | 1253 |
| S2 | | 50%Viscose PCMs: 50% Bamboo | 106 | 562.2 | 88.7 | 11.41 | 7.1 | 906 |
| S3 | Bique | 50%Viscose PCMs: 50% Lyocell | 123 | 773 | 87 | 9.42 | 8.4 | 1114 |
| S4 | | 50%Viscose PCMs: 50% Bamboo | 128.3 | 610.5 | 80 | 8.7 | 6.1 | 772.3 |

## 3-1 Air Permeability

Table (2) and Figures (4) and (5) show the effect of research variables on the air permeability test results of the produced headscarf fabrics.



| Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|
| 97.4 % packing factor: 2.6 % porosity | 96.4 % packing factor 3.6 % porosity | 91.9 % packing factor: 8.1 % porosity | 90.8 % packing factor: 9.2 % porosity |

Figure (4) Porosity & Packing Factor of Produced Samples Using Image Analysis Method

### 3-1-1 Effect of Weave Structure on Air Permeability

It can be noticed from Figures (1) and (5) that Piqué weave structure has recorded the high rates of fabric air permeability compared to Matt Rib weave structure. This is due to increases the float length in Piqué weave structure leads to decrease number of intersections per unit area in the produced fabrics, which leads to increases the porosity of fabrics. As a result, the air permeability of produced fabrics increases.

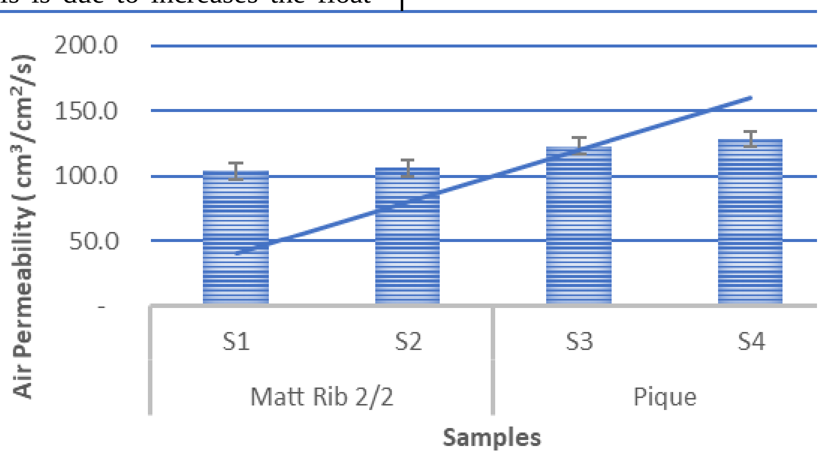



Figure (5) Effect of Weave Structure on Air Permeability

### 3-1-2 Effect of Weft Materials on Air Permeability

It can be observed from Figures (4) and (6) and Table (2) that the Bamboo yarn has recorded the highest rates of air permeability followed by Lyocell fiber. This can be attributed to a specific cross-sectional shape, air gaps, and micro holes of Bamboo fibers as shown in Figure (7). So as the result the fabric becomes more porosity and hence the air permeability increased by using Bamboo compared to Lyocell. [42]

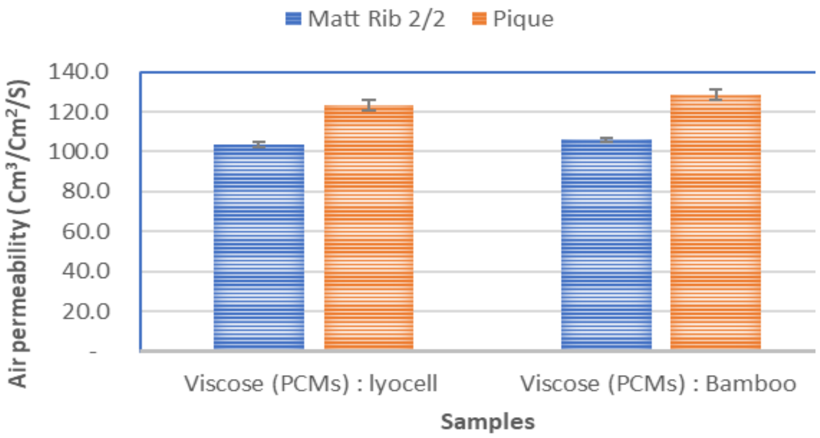
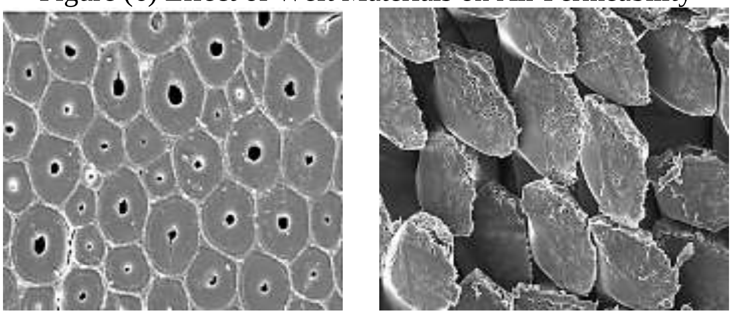



Figure (6) Effect of Weft Materials on Air Permeability



A B

Figure (7) SEM Image of Using Weft Materials Cross-Section (A) Bamboo and (B) Lyocell

**3-2 Moisture Vapor Transport Rate (MVTR)**

Table (2) and Figures (8) and (9) show the results of moisture vapour transport rate test carried out on the produced headscarf fabrics.

**3-2-1 Effect of Weave Structure on (MVTR)**

It is clear from Figure (8) that Piqué weave structure has recorded the high rates of moisture vapour transport rate compared to Matt Rib weave structure. This is due to Piqué weaves tend to be more porous, providing better ventilation and allowing moisture vapor to pass through more freely than Matt Rib weaves.

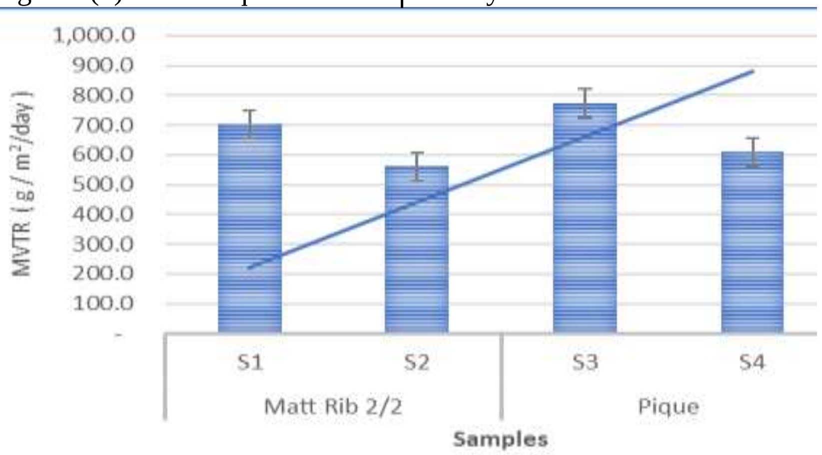



Figure (8) Effect of Weave Structure on Moisture Vapour Transport Rate

**3-2-2 Effect of Weft Materials on (MVTR)**

From Figure (9) and Table (2) it can be conducting that the Lyocell yarn has recorded the highest rates of (MVTR) followed by Bamboo yarn. This is due to the diffusion rate of water vapour along the textile material depend on the water vapor diffusivity of the fibre. Diffusivity of the material increasing with the increase in moisture regain. [43] Consequently, samples made with Lyocell materials have higher water vapor permeability due to the higher moisture retention rate of Lyocell fibres (13%) compared to Bamboo fibres (11%).

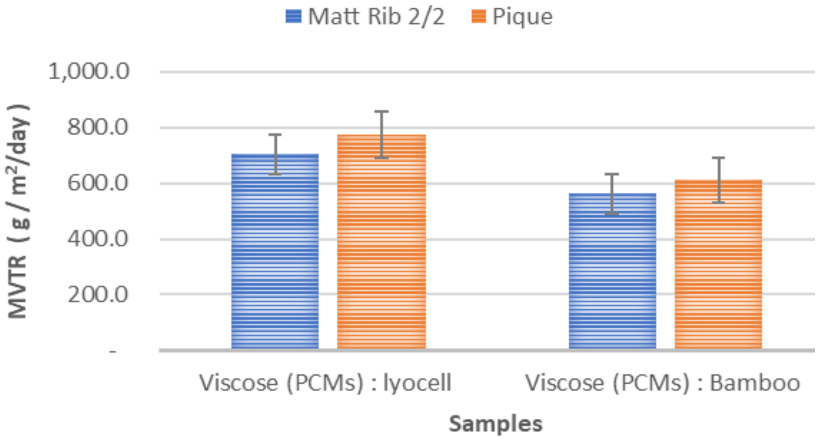



Figure (9) Effect of Weft Materials on (MVTR)

**3-3 Fabric Stiffness**

Table (2) and Figures (10) and (11) show the effect of research variables on the stiffness test results of the produced headscarf fabrics.

**3-3-1 Effect of Weave Structure on Fabric Stiffness**

It can be seen from Figure (10) and Table (2) that Piqué weave has scored the low rates of fabric stiffness compared to Matt Rib 2/2. This is because textiles with long floats in their weave structure can afford greater flexibility. Therefore, the bending resistance of manufactured fabrics decreases when Piqué weave structure is used.

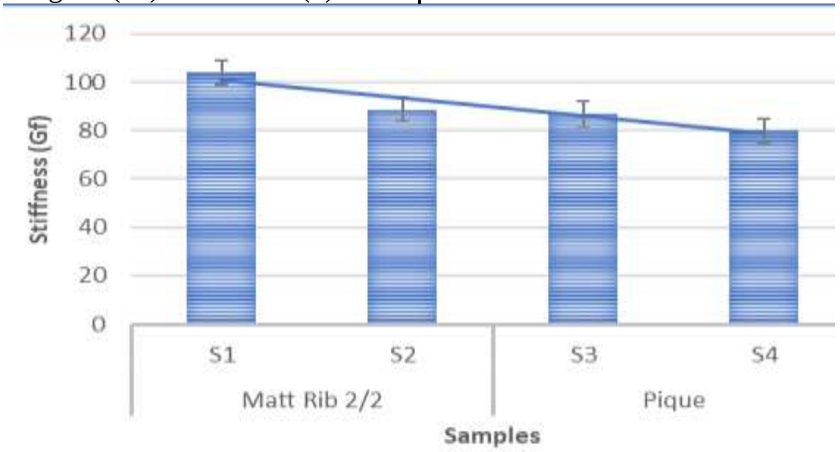



Figure (10) Effect of Weave Structure on Fabric Stiffness

**3-3-2 Effect of Weft Materials on Fabric Stiffness**

From Table (2) and Figure (11), it is observed that the Bamboo as weft material improves the bending characteristic of the final produced fabric, followed by Lyocell. This is due to the fact that the lighter fabrics tend to be more flexible, so as a result, Bamboo as a weft material, which achieves a lower mass per unit area as shown in Table (1) leads to a decrease in bending resistance compared to Lyocell materials.

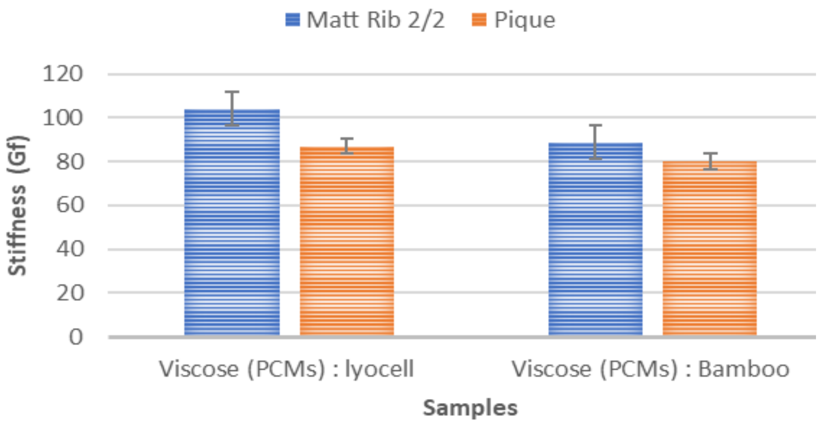



Figure (11) Effect of Weft Materials on Fabric Stiffness

**3-4 Horizontal Wicking**

Table (2) and Figures (12) and (13) show the effect of research variables on the horizontal wicking test results of the produced headscarf fabrics.

**3-4-1 Effect of Weave Structure on Horizontal Wicking**

From Figures (12) and Table (2) it can be seen that, the horizonal wicking rate of Matt Rib weave highest than Piqué weave. This is owing to decreases the float length in the Matt Rib weave as shown in the Figure (1) which leads to an increase in routing points in this samples compared to samples with Piqué weave structure. So, as the result the horizonal wicking rate increases.

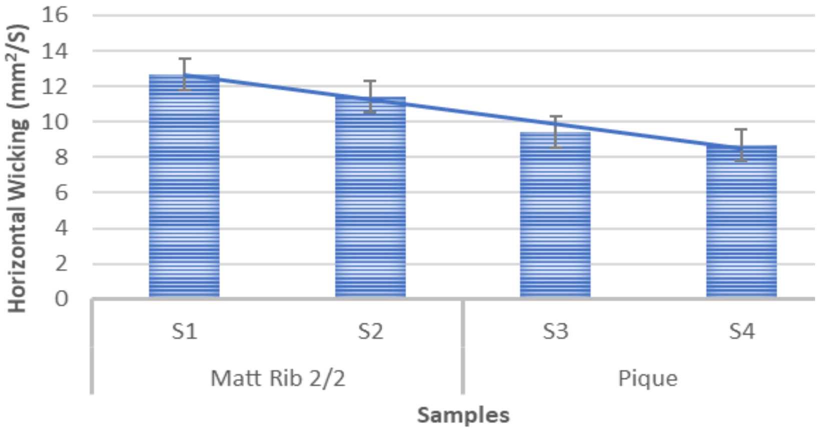



Figure (12) Effect of Weave Structure on Horizontal Wicking

**3-4-2 Effect of Weft Materials on Horizontal Wicking**

From Figure (13) and Table (2) it can be conducting that the Lyocell yarn has recorded the highest rates horizontal wicking followed by Bamboo yarn. This can be attributed to the structure of Lyocell fiber is composed of nano-fibrillar cellulose, featuring numerous non-swelling crystalline microfibers alongside highly hydrophilic crystalline nano-fibrils. These components are organized in a consistent arrangement, resulting in a nanofibrillar, non-porous structure. [44] So, as a result fluid transport across the surface of the fabric, enhancing horizontal wicking.

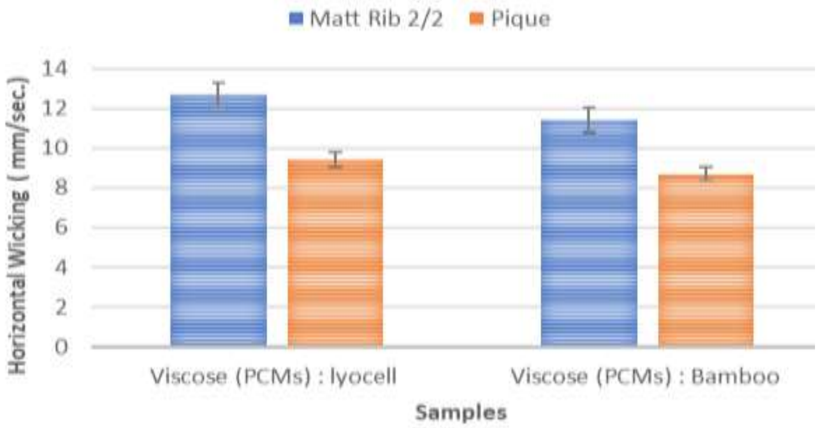



Figure (13) Effect of Weft Materials on Horizontal Wicking

**3-5 Latent Heat**

Table (2) and Figures (14) and (15) show the effect of research variables on the latent heat test results of the produced headscarf fabrics.

**3-5-1 Effect of Weave Structure on Latent Heat**

It can be observed from Figure (14) and Table (2) that the Matt Rib weave structure has recorded the highest rates of latent heat followed by Piqué weave structure. This can be attributed to a higher packing factor percentage in produced fabric as shown in Figure (**4**), leads to increase the percentage of PCMs in the sample. So as the result the latent heat of produced headscarf fabrics increases and vice verses.

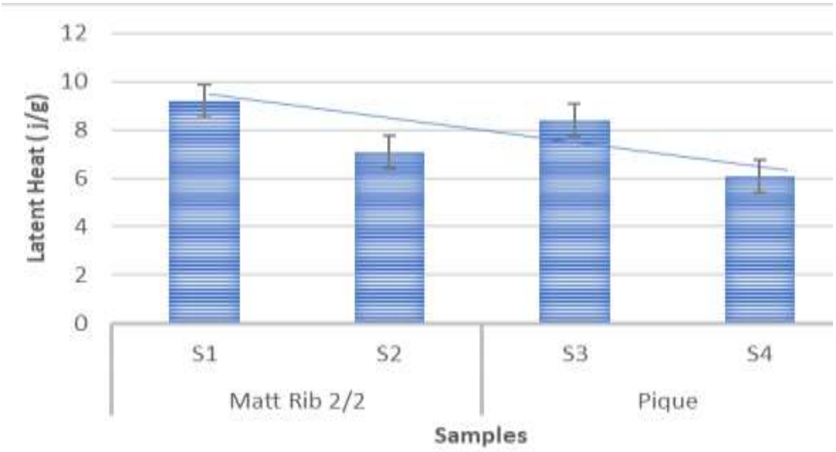



Figure (14) Effect of Weave Structure on Latent Heat

**3-5-2 Effect of Weft Materials on Latent Heat**

It can be seen from Figure (15) and Table (2) that the Lyocell as weft material has recorded the highest rates of latent heat followed by Bamboo materials. This can be attributed to Lyocell fibers exhibit relatively higher thermal conductivity than Bamboo fibers due to their dense, homogeneous structure. This facilitates faster and more efficient heat exchange between the PCM and the surroundings, enhancing the latent heat performance.

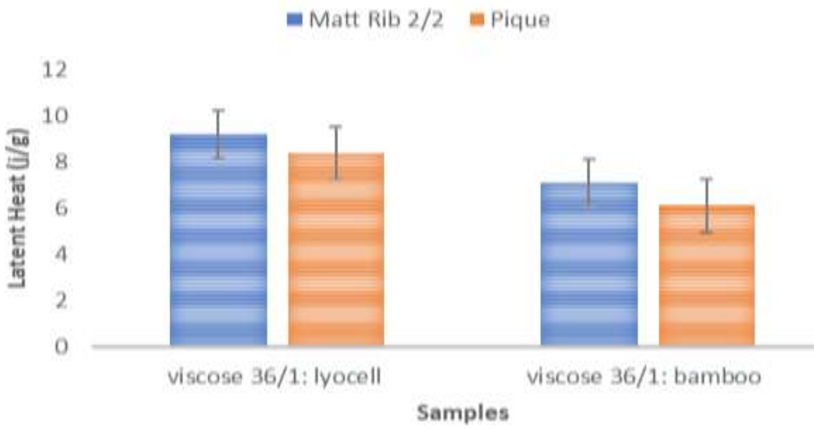



Figure (15) Effect of Weft Materials on Latent Heat

**3-5 Heat Capacity per Square Meter**

Table (2) and Figures (16) show the effect of research variables on the heat capacity per square meters test results of the produced headscarf fabrics.

**3-5-1 Effect of Fabric's Weight on Thermal Capacity**

From Figure (16) there is a direct relationship between the fabric weight and latent heat of fabric's meter square. This is due to increase in fabric weight increases the PCMs percentage in the fabrics which leads to an in increase in the latent heat per meter square.

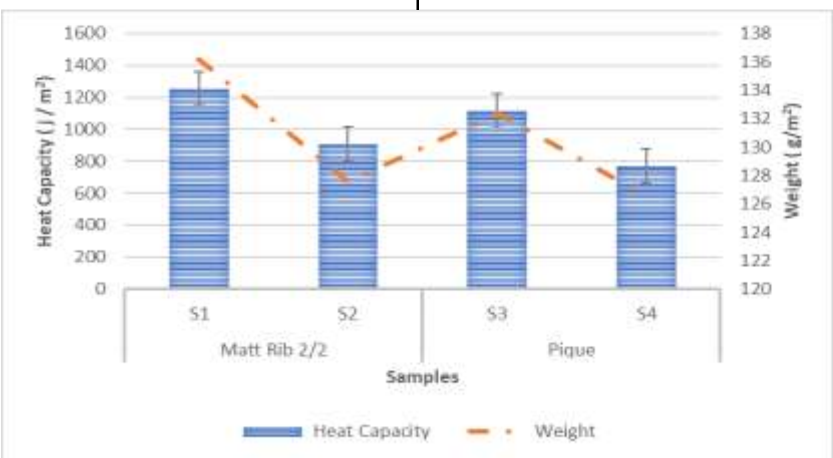



Figure (16) Effect of Weave Structure on Fabric Heat Capacity

## IV. Conclusions:

The main objective of this work was manufacturing a blended woven headscarf fabrics using three weft materials and blended as following ratio (50 % viscose PCM: 50 % Lyocell & 50 % viscose PCM: 50 % Bamboo) with two weave structures (Matt Rib 2/2 & Piqué) and examining the effect of this parameters on comfort and heat capacity properties. From the results, statistical analysis and discussion concerning with the comfort properties of produced fabrics evidently showed that:

- Air permeability property of produced headscarf fabrics have been increased by using Piqué weave. Whilst the Bamboo as weft materials have been achieved the highest rate of air flow through both side of fabric.
- Piqué weave has recorded higher rates of Moisture Vapour Transport Rate (MVTR). However, the Lyocell has been recorded the highest rates of (MVTR).
- Piqué weave has recorded lowest rates of fabric stiffness. Whilst the Bamboo as weft material has scored the smaller rates of fabric stiffness.
- Horizontal wicking property of produced headscarf fabrics have been increased by using Matt Rib 2/2 as weave structure. However, the Lyocell has been achieved the highest rates of horizontal wicking.
- Matt Rib weave has recorded higher rates of fabric latent heat compared to Piqué weave. Whilst the Lyocell has recorded the highest rates of latent heat.
- There is a direct relationship between fabric's weight and the heat capacity of produced headscarf fabrics.

## References


1- C. Byrne, "Technical textiles market – an overview," Handb. Tech. Text., pp. 1–23, 2000, doi: 10.1533/9781855738966.1.

2- S. Zhezhova, S. Jordeva, S. Golomeova-Longurova, and S. Jovanov, "Application of technical textile in medicine," Tekst. Ind., vol. 69, no. 2, pp. 21–29, 2021, doi: 10.5937/tekstind2102021z.

3- A. R. H. and S. C. Anand, Handbook of Technical Textiles, 1st ed. Woodhead Publishing Limited in association with The Textile Institute, 2000. doi: 10.1533/9781855738966.372.

4- I. I. of T. Delhi, "Industry in India Technical Textiles Industry in India, Opportunities and Challenges, Baseline Study," 2020.

5- National Composites Network, "Best Practice Guide: Technical Textiles and Composite Manufacturing".

6- Z. Ahmad, M. S. Naeem, A. Jabbar, and M. Irfan, "Fibers for Other Technical Textiles Applications," Top. Mining, Metall. Mater. Eng., no. August, pp. 201–220, 2020, doi: 10.1007/978-3-030-49224-3_10.

7- S. Marwaha, V. Satyam, and A. Kulkarni, "Emerging Opportunity in Technical Textiles," Asian Textile Journal, vol. 15, no. 6. pp. 81–86, 2006.

8- R. Guru, A. Kumar, D. Grewal, and R. Kumar, "Study of the ImplanTable and Non-ImplanTable Application in Medical Textile," Next-Generation Text., pp. 1–14, 2023, doi: 10.5772/intechopen.103122.

9- Selim Molla, Md Minhajul Abedin, and Iqtiar Md Siddique, "Exploring the versatility of medical textiles: Applications in implanTable and non-implanTable medical textiles," World J. Adv. Res. Rev., vol. 21, no. 1, pp. 603–615, 2024, doi: 10.30574/wjarr.2024.21.1.0058.

10-S. Akter, A. Y. M. A. Azim, and M. A. Al Faruque, "Medical textiles: significance and future prospect in Bangladesh," Eur. Sci. Journal, ESJ, vol. 10, no. 12, pp. 1857–7881, 2014, [Online]. Available: https://eujournal.org/index.php/esj/article/view/3196

11-S. M. Maruf Hasan, M. Shahjalal, J. H. Mridha, and A. M. R. Alam, "Medical Textiles: Application of ImplanTable Medical Textiles," Glob. J. Med. Res., pp. 17–24, 2019, doi: 10.34257/gjmrkvol19is4pg17.

12-H. M. Mrcsed and C. Fti, "Sustainable Medical Textiles".

13-Wen Zhong, "An Introduction to Healthcare and Medical Textiles," Ph.D. University of Manitoba, 2021. doi: 10.1201/9781003170570.

14-M. M. Pritom et al., "Phase change materials in textiles: synthesis, properties, types and applications – a critical review," Text. Res. J., 2024, doi: 10.1177/00405175241246822.

15-T. Ponnapally, T. Bathula, and G. Dornala, "DEVELOPMENT OF PCMs BASED TEXTILES FOR MILITARY APPILCATIONS," Int. Res. J. Eng. Technol., vol. 6, no. 3, pp. 2107–2116, 2019.

16-E. Khalil, "Application of Phase Change Materials in Textiles: A Review," Int. J. Res. Rev., vol. 2, no. 5, p. 281, 2015, [Online]. Available: www.ijrrjournal.com

17-S. Nagar and P. K. Singh, "A short review on the Industrial applications of phase change materials," IOP Conf. Ser. Mater. Sci. Eng., vol. 1116, no. 1, p. 012006, 2021, doi:

10.1088/1757-899x/1116/1/012006.
18-A. Sharma, Nanocomposite Materials for Biomedical and Energy Storage Applications. 2021. doi: 10.5772/intechopen.95130.
19-F. S. BAYRAKTAR and R. KÖSE, "PHASE CHANGE MATERIALS: TYPES, PROPERTIES and APPLICATIONS in BUILDINGS," Kırklareli Üniversitesi Mühendislik ve Fen Bilim. Derg., vol. 8, no. 1, pp. 190–210, 2022, doi: 10.34186/klujes.1126167.
20-M. Zare and K. S. Mikkonen, "Phase Change Materials for Life Science Applications," Adv. Funct. Mater., vol. 33, no. 12, 2023, doi: 10.1002/adfm.202213455.
21-S. Hagman, "The Application of Microencapsulated Biobased Phase Change Material on Textile," 2016, [Online]. Available: https://urn.kb.se/resolve?urn=urn:nbn:se:hb:diva-10266
22-D. H. Elgohary and H. S. Hawas, "Enhancing the comfort properties of military clothing using phase change materials (PCMs) and Bamboo ," J. Text. Assoc., vol. 82, no. 1, pp. 26–34, 2021.
23-M. A. Ali, K. M. Seddik, and A. G. Hassabo, "Polyester fibres enhanced with Phase Change Material (PCM) to maintain thermal stability," Egypt. J. Chem., vol. 64, no. 11, pp. 6593–6613, 2021, doi: 10.21608/ejchem.2021.92104.4367.
24-E. Z. Mostafa, Shaimaa, "Using Microfibers to Optimize the Functional Properties of Janitorial Staff Uniforms," Herit. Des. J., vol. 4, no. 1, pp. 1090–1110, 2024, doi: 10.21608/jsos.2024.314550.1613.
25-H. Mehling, M. Brütting, and T. Haussmann, "PCM products and their fields of application - An overview of the state in 2020/2021," J. Energy Storage, vol. 51, no. March, p. 104354, 2022, doi: 10.1016/j.est.2022.104354.
26-J. Bao et al., "Applications of phase change materials in smart drug delivery for cancer treatment," Front. Bioeng. Biotechnol., vol. 10, no. September, pp. 1–11, 2022, doi: 10.3389/fbioe.2022.991005.
27-D. Dhingra and T. Agarwal, "Episode IV : PCM AND ITS APPLICATION IN MEDICAL DEVICES AND HEALTHCARE Death Causes in New-borns," no. May, pp. 1–5, 2019.
28-M. He et al., "Recent applications of phase-change materials in tumor therapy and theranostics," Biomater. Adv., vol. 147, no. January, p. 213309, 2023, doi: 10.1016/j.bioadv.2023.213309.
29-M. S. Aslam, S. Naveed, A. Ahmed, Z. Abbas, I. Gull, and M. A. Athar, "Side Effects of Chemotherapy in Cancer Patients and Evaluation of Patients Opinion about Starvation Based Differential Chemotherapy," J. Cancer Ther., vol. 05, no. 08, pp. 817–822, 2014, doi: 10.4236/jct.2014.58089.
30-N. Kumar, "Updated clinical guidelines on the oral management of oncology patients," Fac. Dent. J., vol. 10, no. 2, pp. 62–65, 2019, doi: 10.1308/rcsfdj.2019.62.
31-C. Loprinzi, W. Bensinger, and D. Peterson, "Understanding and managing chemotherapy side effects," pp. 4–7, 2018.
32-H. K. Chan and S. Ismail, "Side effects of chemotherapy among cancer patients in a Malaysian general hospital: Experiences, perceptions and informational needs from clinical pharmacists," Asian Pacific J. Cancer Prev., vol. 15, no. 13, pp. 5305–5309, 2014, doi: 10.7314/APJCP.2014.15.13.5305.
33-N. Prasongsook, "Common side effects of chemotherapy," Thai Cancer, vol. 21, pp. 1–8, 2016.
34-Breastcancer.org, "Managing Chemotherapy Side Effects | Breastcancer.org," Lippincott NursingCenter, no. July, pp. 1–5, 2023, [Online]. Available: https://www.breastcancer.org/treatment/chemotherapy/side_effects
35-West Midlands Cancer Alliance Systemic Anticancer Treatment (SACT) Expert Advisory Group, "Scalp Cooling Guidelines for Adult Oncology Patients," pp. 1–12, 2020.
36-S. Abd El-Moneam Ahmed, W. Ismail Shereif, G. ElSayed Hafez, and Z. Gamal Mohamed Ellatif Abouelezz, "Factors Influencing Using Scalp Cryotherapy to Promote Hair Regrowth in Breast Cancer Patients Receiving Chemotherapy," Int. Egypt. J. Nurs. Sci. Res., vol. 3, no. 2, pp. 52–71, 2023, doi: 10.21608/ejnsr.2023.277686.
37-C. Education, "Hair Loss and Your Cancer Treatment," pp. 1–19, [Online]. Available: https://www.mskcc.org/cancer-care/patient-education
38-K. M. Kokolus, C. C. Hong, and E. A. Repasky, "Feeling too hot or cold after breast cancer: Is it just a nuisance or a potentially important prognostic factor?," Int. J. Hyperth., vol. 26, no. 7, pp. 662–680, 2010, doi: 10.3109/02656736.2010.507235.
39-BC Cancer Agency, "Coping with / Preventing Oxaliplatin Cold Dysesthesias," pp. 2–3, 2014, [Online]. Available: http://www.bccancer.bc.ca/drug-database-site/Drug Index/OxaliplatinColdDysesthesia_Patient_Handout_1Jan2015.pdf

40-R. Hughes, "Chemo Side Effects: Temperature Regulation." https://advancedbreastcancer.net/living/temperature-regulation-side-effect?utm_source=chatgpt.com

41-Ruchi Garg, "Cancer-related hot flashes and night sweats," Gynecologic Oncology, City of Hope Atlanta, Chicago and Phoenix. https://www.cancercenter.com/integrative-care/hot-flashes?utm_source=chatgpt.com

42-K. Aruchamy, S. P. Subramani, S. K. Palaniappan, S. K. Pal, B. Mylsamy, and V. Chinnasamy, "Effect of Blend Ratio on the Thermal Comfort Characteristics of Cotton/Bamboo Blended Fabrics," J. Nat. Fibers, vol. 19, no. 1, pp. 105–114, 2022, doi: 10.1080/15440478.2020.1731903.

43-hafez hawas, "A Study on Comfort Properties of Banana / Cotton Blend Woven Fabrics," J. Des. Sci. Appl. Arts, vol. 2, no. 1, pp. 140–149, 2021, doi: 10.21608/jdsaa.2021.35112.1069.

44-A. I. Emara, "Improving the Performance of Terry Fabrics to be used as Pilgrimage," Int. Des. J., vol. 10, no. 3, pp. 397–413, 2020.