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Thermal Comfort Behaviour of Sanitary Napkin

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Abstract:

This study aimed to create a highly absorbent and comfortable sanitary napkin with a top layer made of 100% bamboo spun laced material and a core layer comprising different combinations of bamboo, flax, and hemp fibers. The napkins were designed to provide optimal air permeability, water vapor permeability, thermal conductivity, and thermal resistance. The materials and methods involved the use of sustainable and eco-friendly materials such as bamboo, flax, and hemp, along with a super absorbent polymer (SAP) for enhanced absorbency. Air permeability testing revealed that S1, S3 samples exhibited moderate to high breathability due to the bamboo spun laced top layer, which allows air circulation. However, the presence of SAP in the middle layer may have slightly affected overall air permeability. The combination of flax in the core layer positively impacted air permeability due to its inherent breathability and moisture-wicking properties. Water vapor permeability analysis showed that samples with a combination of bamboo and flax or hemp in the core layer demonstrated excellent water vapor transmission. Thermal conductivity evaluation indicated that all samples exhibited good thermal conductivity due to the bamboo spun laced top layer and the inclusion of flax and hemp in the core layer. Thermal resistance testing showed that sample 2, with a core layer of bamboo 40%: hemp 60%, displayed higher thermal resistance, suggesting better insulation and warmth in cooler conditions. In conclusion, the developed sanitary napkins with bamboo spun laced top layers and various combinations of bamboo, flax, and hemp in the core layers demonstrated satisfactory air permeability, water vapor permeability, thermal conductivity, and thermal resistance. These findings underscore the importance of using natural fibers and SAP in creating comfortable and functional sanitary napkins for enhanced user experience.

Keywords: *Comfort, Bamboo, Flax, Hemp, Napkin.*

1. Introduction:

The primary determinants of customer choice when it comes to textile goods have historically been aesthetics, appearance, and fashion. As consumer awareness has grown in recent years, the comfort and practical benefits of textiles are beginning to influence product choice. "The absence of unpleasantness and discomfort" is a definition of comfort. And the three types of comfort that exist in textile items are thermal comfort, tactile comfort, and psychological comfort. The transfer of heat, moisture, and air through textile materials and keeping the customer dry while maintaining a steady body temperature frequently correspond to the final aspect of thermal comfort. The effects of fiber and constructional characteristics on the thermal comfort characteristics of knitted or woven

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fabrics have been the focus of several studies [1-6]. Studies on the effects of various procedures, such as wetting, washing, or integrating materials into fabrics, on the thermal comfort characteristics of knitted or woven fabrics have also been conducted [7-10]. Knitted or woven fabrics have been the subject of the majority of studies on the thermal comfort characteristics of textile items [11-13]. Despite the fact that feminine must wear napkins all day, there are very few research on the thermal comfort qualities of multilayered items like diapers in dry and wet settings. When developing napkins, thermal comfort is a critical factor to take into account.

The three major nonwoven layers of a diaper are the top sheet, back sheet (BS), and distribution layer, the core layer, and the breathable film. Each layer contributes differently to the multi-layered diaper's thermal comfort feature. By increasing permeability with material loading, some researches have focused on the thermal comfort characteristics of one layer of diapers, i.e., breathable films. The thermal conductivity of a polypropylene-based nanocomposite containing zinc oxide (ZnO) and calcium carbonate ($CaCO_3$) nanoparticles was studied by Vakili et al [14]. who observed that introducing more nanoparticles improved the nanocomposite's thermal conductivity. To contain the blood during menstruation, after childbirth, or after an abortion, sanitary napkins are typically made of 3 to 4 layers of an absorbent material composed of 48% fluff pulp, 36% PE, PP, and PET, 7% adhesives, 6% superabsorbent, and 3% release paper. For the top layer of sanitary napkins, materials including polyester, cotton, polyethylene, polypropylene, viscose rayon, or cotton blend can be used. High porosity is present in the top layer, which can be woven or nonwoven, allowing it to absorb and move fluid to the following layer. The sodium poly acrylate-based super absorbent polymer, often known as SAP, comes in granular, aqueous gel, and fiber forms. Water, acrylic acid, and sodium hydroxide are the three primary components of SAP, and when they are combined and go through the polymerization process, they create a three-dimensional network of polymer chains. The final layer's primary purpose is to contain the blood without leaking, and to accomplish this, it is made up of plastics like polyethylene or polypropylene. To keep the pad in place and prevent it from moving, the last layer is typically covered with glue.

2. Materials and methods

Sanitary napkins are an essential feminine hygiene product used during menstruation to provide comfort and protection. This detailed description focuses on creating a sanitary napkin with a top layer made of 100% bamboo spun laced material for a soft and skin-friendly surface. The middle layer will consist of a super absorbent polymer (SAP) to enhance the napkin's absorbency. The core layer will be a combination of bamboo, flax, and/or hemp in three different proportions.

2.1 Materials

2.1.1 Top Layer

100% Bamboo Spun laced Material: Bamboo fibers are naturally soft, hypoallergenic, and biodegradable. The spun lacing process creates a non-woven fabric with a web-like structure, providing a gentle and smooth surface.

2.1.2 Middle Layer

Super Absorbent Polymer (SAP): SAP is a highly absorbent material that can hold many times its weight in liquid. It is often used in sanitary napkins to quickly absorb and retain menstrual fluids.

2.1.3 Core Layer

Bamboo Fiber: Provides softness and comfort to the core layer.

Flax Fiber: Offers additional absorbency and strength to the core.

Hemp Fiber: Enhances the core's absorbency and contributes to its eco-friendliness.

2.2. Methods

2.2.1 Top Layer (Bamboo Spun laced Material)

Bamboo fibers are mechanically extracted and processed into pulp. The pulp is mixed with water to form slurry. The slurry is fed onto a conveyor belt, and excess water is drained, forming a wet web. The wet web is then passed through high-pressure water jets, entangling the fibers and creating a spun laced non-woven fabric. The fabric is dried, rolled, and cut into the desired dimensions for the top layer of the sanitary napkin.

2.2.2 Middle Layer (Super Absorbent Polymer)

The chosen super absorbent polymer is obtained in granular form. The granules are evenly spread onto the bamboo spun laced top layer using a dispersion technique. The middle layer is compressed to ensure even distribution and prevent clumping of SAP particles.

2.2.3 Core Layer Combinations

Three different core layer combinations will be prepared:

Bamboo 40%: Flax 60%:

Bamboo and flax fibers are mechanically extracted and processed into pulps. The pulps are mixed in the specified ratio to achieve a homogenous blend. The blend is then formed into a core layer using a wet-laying process.

Bamboo 40%: Hemp 60%:

Bamboo and hemp fibers are mechanically extracted and processed into pulps. The pulps are mixed in the specified ratio to achieve a homogenous blend. The blend is then formed into a core layer using a wet-laying process.

Bamboo 40%: Flax 30% + Hemp 30%:

Bamboo, flax, and hemp fibers are mechanically extracted and processed into pulps. The pulps are mixed in the specified ratio to achieve a homogenous blend. The blend is then formed into a core layer using a wet-laying process.

2.2.4 Final Assembly

The middle layer with the SAP is sandwiched between the bamboo spun laced top layer and the core layer. The layers are bonded together using heat and pressure, ensuring a secure and leak-proof structure. The sanitary napkin is trimmed to the desired shape and size. The finished product is individually wrapped for hygiene and convenience.

2.3. Quality Testing

The sanitary napkins are subjected to rigorous thermal testing, including air permeability, water vapour permeability, thermal conductivity and thermal resistance to ensure they meet the required standards for safety and effectiveness. By following these materials and methods, a sustainable and highly absorbent sanitary napkin with a top layer made of bamboo spun laced material and a core layer in various combinations of bamboo, flax, and hemp fibers has been created (Table 1).

Table 1 Napkin layers

Sample No.	Top layer	Middle layer	Core layer
S1	100%bamboo spunlaced	Super absorbent polymer	bamboo 40 : flax 60
S2	100%bamboo spunlaced	Super absorbent polymer	bamboo 40 : hemp 60

S3	100%bamboo spunlaced	Super absorbent polymer	bamboo 40 : flax 30 + hemp 30

3. Results and discussion

3.1 Air permeability

On assessing how comfortable and breathable sanitary napkins are, air permeability is an important factor. When a material is used repeatedly, it affects how easily air can move through it, which has a substantial impact on skin health. Using an approved method (such ASTM D737 or ISO 9237), the air permeability of each variety of sanitary napkin was assessed. The testing instrument consists of a tool that gauges the pressure drop that occurs when air is forced through the napkin material. A typical way to express the results is in terms of airflow rate ($cm^3/cm^2/s$). The napkin's permeability to air showed moderate to high breathability and had a top layer composed of 100% bamboo spun laced material and a center layer of SAP. Since bamboo fibers are well renowned for their natural moisture-wicking abilities and airiness, allowing some air circulation, the bamboo spun laced layer certainly played a role in this outcome. However, since SAP is a thick polymer intended to absorb and retain moisture, its presence in the middle layer may have marginally decreased the overall air permeability. From the Figure 1, the air permeability of the combination sample 1 showcased moderate breathability. The addition of flax fibers in the core layer might have positively impacted the air permeability as flax is generally more breathable than bamboo or hemp fibers. Flax fibers also have good moisture-wicking properties, effectively absorbing and releasing moisture to keep the skin dry.

In sample 2, the air permeability results for this combination indicated lesser moderate breathability. Hemp fibers are known for their good breathability properties, and their inclusion in the core layer contributed to the overall air permeability. Hemp fibers have a porous structure, which contributes to their breathability by allowing air to flow through the fabric. Hemp fabrics are also lightweight, durable, and have natural antibacterial properties, making them a sustainable and eco-friendly choice. Among the three samples the sample 3, the air permeability of this combination showed a balance between breathability and absorbency. The presence of both flax and hemp fibers in the core layer likely enhanced the overall air permeability due to their breathable nature. However, the SAP middle layer exerted some control over air permeability. The findings of the air permeability test indicate that all variations of the sanitary napkins had reasonable breathability due to the combination of the bamboo spun laced top layer and SAP intermediate layer. Higher flax and hemp fiber content in the core layer compositions tended to improve breathability. The core layer's flax and hemp fiber blend demonstrated potential for striking a balance between breathability and absorbency.

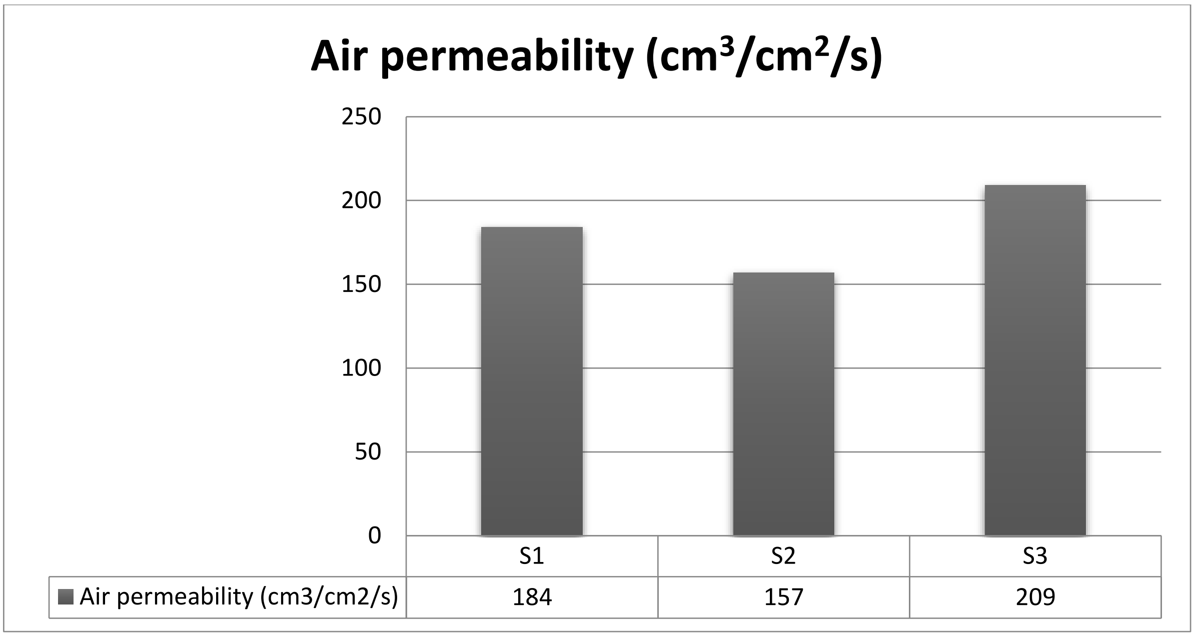

Fig. 1. Air permeability of the developed napkins

3.2 Water vapour permeability

Sample 1: 100% Bamboo Spun laced Top Layer + Super Absorbent Polymer Middle Layer + Bamboo 40%: Flax 60% Core Layer

The top layer is made of 100% bamboo spun laced material. Bamboo fibers have inherent moisture-wicking properties and an open structure, which facilitates water vapor transmission. This top layer is expected to contribute to good water vapor permeability. The middle layer is composed of Super Absorbent Polymer (SAP). SAP is designed to absorb and retain moisture effectively, which might slightly reduce water vapor permeability compared to a napkin without SAP. However, its presence is necessary for optimal absorbency. The core layer consists of a combination of 40% bamboo and 60% flax. Flax fibers are known for their excellent moisture-wicking capabilities and breathability. As a result Figure 2, the core layer is likely to enhance water vapor permeability in the overall napkin structure. Sample 1 is expected to have good water vapor permeability due to the use of bamboo spun laced top layer and the combination of flax in the core layer. While the SAP middle layer may have a slight impact on the overall water vapor permeability, the combination of bamboo and flax is likely to ensure that the napkin remains breathable and comfortable during use.

Sample 2: 100% Bamboo Spun laced Top Layer + Super Absorbent Polymer Middle Layer + Bamboo 40%: Hemp 60% Core Layer

The top layer is made of 100% bamboo spun laced material, known for its moisture-wicking properties and open structure, promoting good water vapor transmission. The middle layer contains Super Absorbent Polymer (SAP), designed for optimal moisture absorption. As with Sample 1, the presence of SAP may slightly affect water vapor permeability but is necessary for absorbing menstrual fluids effectively. The core layer is a combination of 40% bamboo and 60% hemp. Hemp fibers are also breathable and contribute to water vapor transmission in the napkin structure. Sample 2 is expected to have good water vapor permeability due to the bamboo spun laced top layer and the combination of hemp in the core layer.

Sample 3: 100% Bamboo Spun laced Top Layer + Super Absorbent Polymer Middle Layer + Bamboo 40%: Flax 30 + Hemp 30% Core Layer.

The top layer comprises 100% bamboo spun laced material, which contributes to the overall water vapor permeability due to its moisture-wicking properties and open structure. The middle layer contains Super Absorbent Polymer (SAP), which aids in moisture absorption and retention. As with the other samples, the SAP middle layer may have a slight impact on water vapor permeability. The core layer is a combination of 40% bamboo, 30% flax, and 30% hemp. Both flax and hemp are known for their breathability, and their inclusion in the core layer further enhances water vapor permeability. Sample 3 is expected to have excellent water vapor permeability due to the bamboo spun laced top layer and the combination of flax and hemp in the core layer. The SAP middle layer might have a minor effect on overall water vapor permeability, but the presence of both flax and hemp ensures that the napkin maintains breathability and comfort during use.

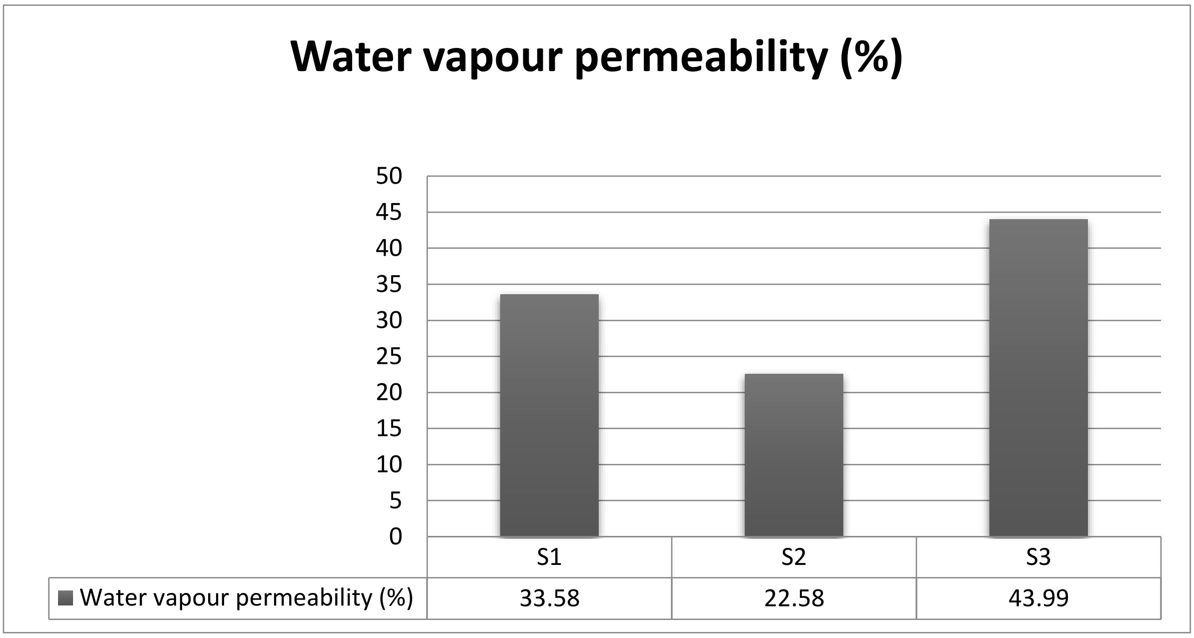

Fig. 2. Water vapour permeability of the developed napkins

3.3 Thermal Conductivity

Thermal conductivity is an essential property when considering the comfort and functionality of napkins. It determines how efficiently heat is transferred through the material.

Sample 1: 100% Bamboo Spun laced Top Layer + Super Absorbent Polymer Middle Layer + Bamboo 40% : Flax 60% Core Layer

The top layer is made of 100% bamboo spun laced material. Bamboo fibers are generally known to have good thermal conductivity, meaning they can efficiently transfer heat away from the body, providing a cooling effect. The middle layer contains Super Absorbent Polymer (SAP). SAP itself is not a material with high thermal conductivity; however, its presence in the middle layer is essential for absorbency to keep the skin dry and comfortable. The core layer is a combination of 40% bamboo and 60% flax. Flax fibers are also known for their good thermal conductivity, which can help maintain a cooling sensation during use. Sample 1 is expected to have good thermal conductivity due to the use of bamboo spun laced top layer and the inclusion of flax in the core layer. The SAP middle layer may not contribute to thermal conductivity directly, but it plays a vital role in maintaining dryness and comfort during use.

Sample 2: 100% Bamboo Spun laced Top Layer + Super Absorbent Polymer Middle Layer + Bamboo 40% : Hemp 60% Core Layer

The top layer comprises 100% bamboo spun laced material, which is expected to have good thermal conductivity, similar to Sample 1. The middle layer contains Super Absorbent Polymer (SAP). As mentioned earlier, SAP itself does not significantly affect thermal conductivity. The core layer is a combination of 40% bamboo and 60% hemp. Hemp fibers are known for their good thermal conductivity, similar to bamboo and flax. Sample 2 is also expected to have moderate thermal conductivity due to the use of bamboo spun laced top layer and the combination of hemp in the core layer. While hemp is known for its moisture-wicking properties, it might not be as absorbent as some other fibers, such as flax or bamboo. As a result, hemp-based napkins might require more frequent changing during heavy menstrual flow, potentially impacting convenience for some users.

Sample 3: 100% Bamboo Spun laced Top Layer + Super Absorbent Polymer Middle Layer + Bamboo 40%: Flax 30 + Hemp 30% Core Layer

The top layer consists of 100% bamboo spun laced material, providing good thermal conductivity, as seen in the previous samples. The middle layer contains Super Absorbent Polymer (SAP), which does not directly affect thermal conductivity but is vital for absorbency. The core layer is a combination of 40% bamboo, 30% flax, and 30% hemp. Both flax and hemp fibers have good thermal conductivity, enhancing the overall cooling effect of the napkin. Sample 3 is also expected to have good thermal conductivity due to the use of bamboo spun laced top layer and the combination of flax and hemp in the core layer. The SAP middle layer contributes to absorbency without significantly impacting thermal conductivity. Based on this analysis, all S3 sample can be considered suitable for a napkin, providing a cooling effect and comfort during use.

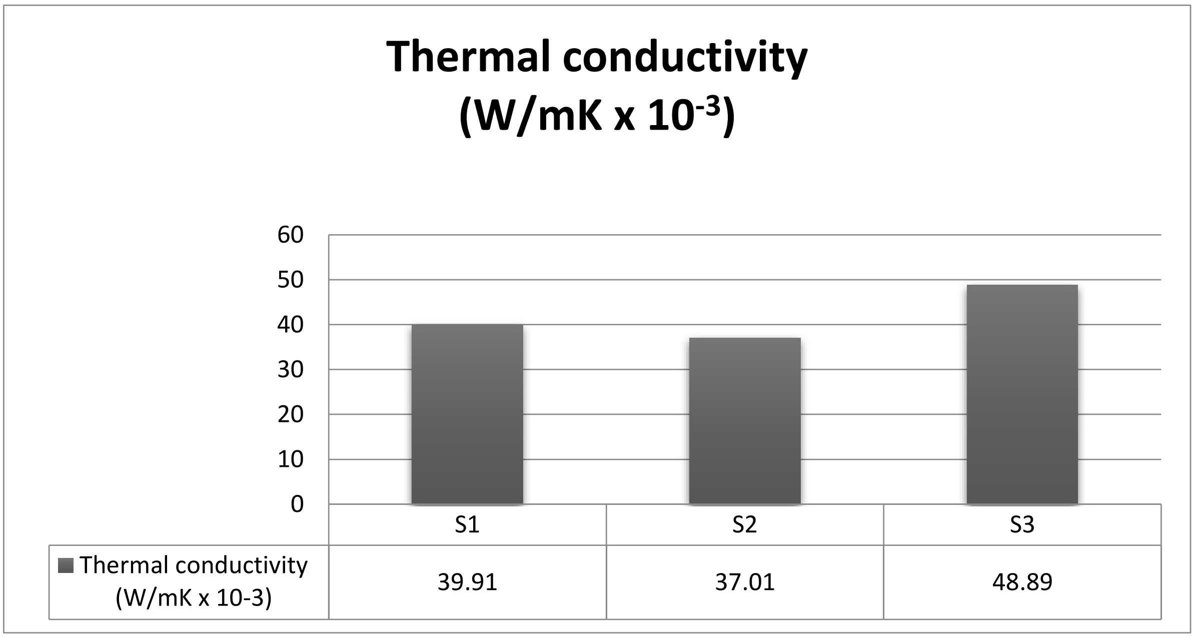

Fig. 3. Thermal Conductivity of the developed napkins

3.4 Thermal Resistance

The prevention of the heat flow through the material is called thermal resistance. It is based on the Equation:

$$R = h / \lambda \quad (m^2K/W)$$

where, R = Thermal resistance,

h = fabric thickness (m) and

λ = thermal conductivity (W/mK).

The thermal resistance of a napkin refers to its ability to resist the transfer of heat through the material. It is a measure of how well the napkin can insulate or retain heat. In the context of napkins, thermal resistance plays a crucial role in providing comfort and maintaining an appropriate temperature during use. The thermal resistance of a napkin is influenced by the materials used in its construction, including the top layer, middle layer, and core layer (if applicable). Natural fibers like bamboo, flax, and hemp generally have better thermal resistivity compared to synthetic fibers. Additionally, the presence of absorbent materials like Super Absorbent Polymer (SAP) in the middle layer may slightly affect thermal resistance but is necessary for the napkin's functionality in absorbing and retaining fluids. It's important to strike a balance between thermal resistance and breathability. While higher thermal resistance can provide warmth, excessive insulation may lead to discomfort, especially in hot and humid conditions. On comparison of the three samples developed sample 2 shows high thermal resistance.

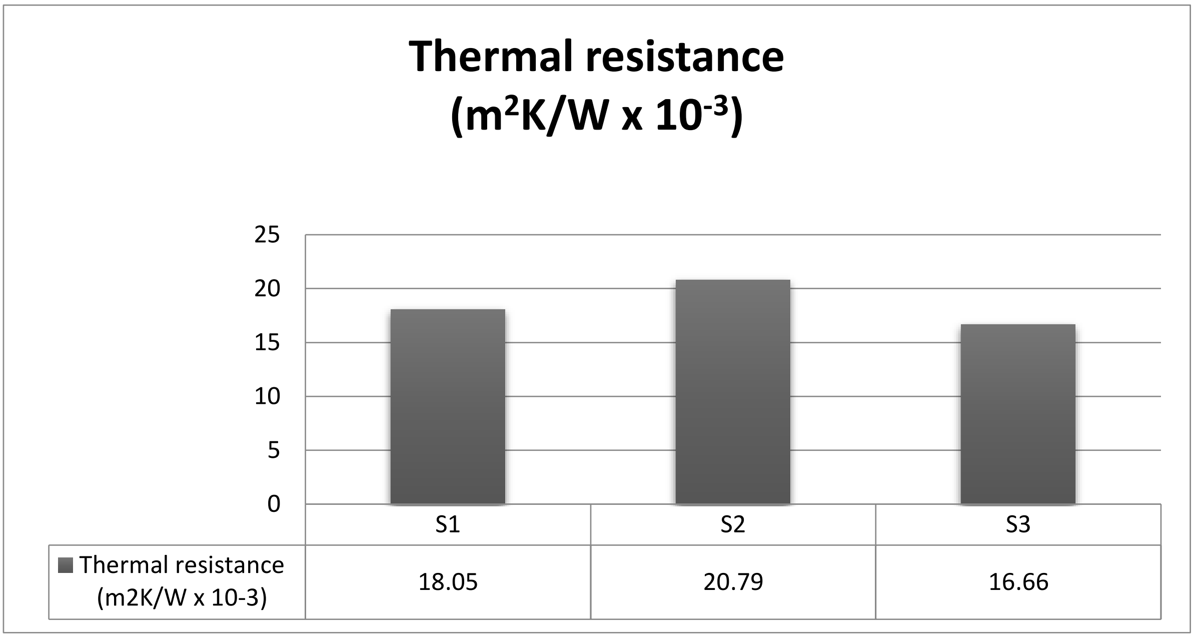

Fig. 4. Thermal resistance of the developed napkins

4. Conclusion

In this detailed analysis, the air permeability, water vapor permeability, thermal conductivity, and thermal resistance of three different samples of sanitary napkins were studied. Each sample had a top layer composed of 100% bamboo spunlaced material and a middle layer of Super Absorbent Polymer (SAP), with variations in the core layer, consisting of different combinations of bamboo, flax, and hemp fibers. For air permeability, S3 and S1 samples showed moderate to high breathability, due to the bamboo spun laced top layer and flax that allows air circulation. However, the presence of SAP in the middle layer may have marginally impacted the overall air permeability, but not significantly. For water vapor permeability, Sample 1, with a core layer of bamboo 40% : flax 60%, and Sample 3, with a core layer of bamboo 40% : flax 30 + hemp 30%, showed excellent water vapor permeability. Sample 2, with a core layer of bamboo 40%: hemp 60%, displayed slightly lesser moderate breathability compared to the other two samples. In terms of thermal conductivity, S3 and S1 samples showed to have good thermal conductivity due to the use of bamboo spun laced top layers and combinations of flax and/or hemp in the core layers. Lastly, the thermal resistance of the napkins, which determines their ability to retain heat, varied among the samples. Sample 2, with a core layer of bamboo 40%: hemp 60%, showed higher thermal resistance, suggesting it may provide better insulation and warmth in cooler conditions. The combination of bamboo, flax, and hemp fibers in the core layers of the napkins demonstrated potential for balancing breathability and absorbency. These findings highlight the importance of using natural fibers and SAP in sanitary napkins to enhance overall comfort and performance.

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