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Investigation on Bi-Layer Knitted Fabric Produced Using Recycled Polyester and Banana Fiber for Improved Moisture and Thermal Comfort Properties

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Abstract

This research investigates thermal comfort characteristics of bi-layer knitted fabrics made of banana fibers and recycled polyester (rPET). The main aim is to maximize thermal comfort of textile products by taking advantage of the distinctive characteristics of these two varieties of eco-friendly materials. Recycled polyester and banana fibers were combined to make the bi-layer knitted materials, which is produced as separate inner and outer layers to maximize performance. The features related to thermal comfort, such as thermal resistance, thermal conductivity, and moisture controls were carefully evaluated. Research results show that the bi-layer structure greatly increases the wearer's comfort level by improving moisture-wicking and thermal insulation. By combining the inherent thermal regulating qualities of banana fibers with the strength and durability of recycled polyester, the optimized fabric exhibits a combined benefit. The evaluation of important aspects of thermal comfort through moisture control, thermal resistance, and thermal conductivity, was carried out. According to the study, the bi-layer construction greatly improves the wearer's comfort by strengthening its capacity to drain away moisture and its effective thermal insulating qualities. The toughness of recycled polyester mixed with the inherent temperature and moisture management properties of banana fibers creates a fabric that is superior in terms of comfort and performance. The study shows that by combining these material, a fabric that meets high requirements for thermal comfort may be created that also encourages sustainability by utilizing natural and recycled fibers.

Keywords: Thermal resistance, Moisture management, Liquid spread, Sustainability, Wicking

INTRODUCTION

Many different types of fibers are used in textile industry and each has unique characteristics that influence the qualities of the end product to be produced in clothing industries. These fibers can be natural have its source from plant or animal and synthetic fibers which is produced using chemicals [1]. Due to increased customer demand for ethically manufactured textiles and environmental concerns, the textile industry has seen a dramatic movement in recent years towards embracing new and sustainable fibers. One of the key techniques in the transition of textile industry in the direction of sustainability is blending novel, sustainable fibers with synthetic fibers [2, 3]. The mechanical strength of fabric can be improved by combining natural and synthetic fibers, and this may impact its durability and functionality [4, 5]. In a research, root fiber showed greater scope as a sustainable substitute for synthetic fibers [6]. Also it is confirmed that the Surface modification of plant fibers significantly enhances the moisture management and thermal comfort [7]. The correct choice of fiber, yarn and

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its different types of fabric production technique plays a major role in developing exact matching fabric for required end product. Different manufacturing techniques are used to manufacture a woven, knitted, and nonwoven fabric which provides unique fabric properties.

Research on combinations of novel textile material for providing enhanced utility and environmental benefits has increased significantly due to the increasing demand for high-performance and sustainable textiles. Recycled polyester (rPET) is being used because of its ability to lower resource consumption and to control plastic pollution and utilization of waste in an alternative way. Banana fibers, a natural fiber is well-known for their superior thermal insulation and moisture management qualities, is being used as complementary materials.

The pseudo-stem of banana plants provides banana fibers, which are a biodegradable and renewable resource. Due to their special qualities such as their low density, high specific strength, and inherent thermal insulation properties, they can improve the performance of textile products [8]. Recycled polyester and banana fibers combined in a bi-layer knitted fabric structure provide an exciting opportunity to maximize thermal comfort without compromising sustainability.

Bi-layer knitted fabrics have been developed where it have two distinctive layers in which the inner layer intended to manage moisture effectively and the outer layer intended to provide thermal insulation, immediate moisture evaporation and durability. If two different fibers with opposite characteristics could combine to produce bilayer structure for achieving balanced temperature and enhanced comfort of the wearer [9].

The evaluation of moisture management and thermal resistance properties of a fabric are the a major impact on moisture and thermal comfort. If a fabric with Low thermal conductivity prevents heat transfer from the body to the outer environment, on the other side a fabric with high thermal resistance holds body heat. Superior moisture wicking keep skin dry and influence the wearer comfort. All these characters are necessary for effective thermal comfort [10, 11]. The thermal comfort properties of bi-layer fabrics have been studied by many researchers and presented in many directions. Researchers recommended that the bi-layer fabric improves moisture management and thermal insulation to improve thermal comfort [12– 14].

The rate of the liquid spreading speed using electrical resistance [15]; the liquid spreading behavior using an image processing technique [16–18]; the capacity of moisture absorb using a sweating cylinder [19]; the moisture management properties of fabric were evaluated [20–22] and researchers studied the transverse wicking of elastic knitted fabric under the extension and recovery using a cyclic stress instrument.

The purpose of this research is to create and evaluate bi-layer knitted fabrics with an emphasis on thermal comfort that are manufactured from recycled polyester and banana fibers. The main aim of the research is to enhance moisture management and thermal resistance by combining banana fibers as inner layer and recycled polyester as outer layer in the bi-layer fabric for achieving overall temperature regulation. A detailed evaluation of the thermal resistance and moisture management characteristics of the produced bi-layer fabric constitutes a main factor for the investigation.

The results of this investigation could help in the development of high-performing, functional textile which is environmental friendly textiles which satisfy the increasing need from consumers for comfortable clothing. Additionally, in order to obtain enhanced thermal comfort characteristics, this study utilizes the natural fibers in combination with recycled materials, considering the potential benefits of banana fibers and recycled polyester.

MATERIALS AND METHODS

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Materials

Banana fibers and recycled polyester were the materials used in this investigation. For this study, recycled polyester yarn of 150 denier, Banana yarn of 30s NE were sourced from the local supplier from the same lot. Single jersey fabric with 100% recycled polyester and 100% banana yarn were produced for this study. Plated structure was chosen for producing bi-layer fabrics with banana as inner layer and recycled polyester as outer layer by feeding all feeders using M/s Year China circular knitting machine of 24 gauge, 20 inch cylinder diameter and 66 feeders. This arrangement of bi-layer is chosen especially to make sure that the outer layer adds durability and thermal insulation, while the inner layer manages moisture and provides softness.

The technical particulars of fabrics are listed in Table 1.

Table 1. Technical Particular of Fabrics.

S.N.	Sample	Construction details		Thickness (mm)	Areal Density (GSM)	Loop length (mm)
		CPI	*WPI*			
	100% Recycled Polyester fabric	48	51	0.41	121	2.8
	100% Banana fabric	44	48	0.51	137	2.8
	Bi layer fabric Recycled Polyester and Banana fabric	47	50	0.56	168	2.7

Methods

Measure of Maximum Wetted Radius Through Moisture Management Tester

Moisture management testing is necessary to evaluate the capacity of the materials to regulate moisture, which is essential for comfort and functionality in a multi range of applications. Using an SDL Atlas Moisture Management Tester (MMT), moisture management characteristics of the conditioned fabric samples were assessed in accordance with AATCC 195-2009. Concentric moisture sensors available in the MMT were used to detect the liquid's spread by electrical resistance as the liquid moved from one side of the cloth to the other side and also began to spread across the surface of the fabric in a radial, multidirectional directions. With MMT, accumulative one-way transport index, spreading speed, wetting time, absorption rate, maximum wetted radius, and overall moisture management capacity can be evaluated. For further discussion and comparison, the results obtained from the maximum wetted radius are taken

Measure of Thermal Resistance

For assessing the thermal resistance of knitted samples, the ASTM D1518 guarded hot plate apparatus is used. Set the hot and cold plate temperatures to predetermined levels. Cover the entire surface of the hot plate with the sample prepared after placing it in the specimen holder. Let the hot plate, cold plate, and guard ring temperatures stabilize at thermal equilibrium, use the heat flux meter and find the specimen's heat flux. Note the variation in temperature between the hot and cold plates and calculate the thermal transmittance.

RESULT AND DISCUSSION

Measure of Maximum Wetted Radius Through Moisture Management Tester

Three different types of knitted materials produced as 100% recycled polyester knitted fabric, 100% banana knitted fabric, and bi-layer knitted fabric shown in Figure 1 (recycled polyester/banana fiber) were measured for the maximum wetted radius using MMT. The measure of wetted radius is an important indicator to identify the capacity of the fabric to regulate moisture, or to spread moisture evenly across its surface is essential for thermal comfort.

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In comparison to the other fabrics, the 100% rPET fabric showed a comparatively smaller wetted radius. This indicates that rPET fibers have a moderate moisture-wicking character and prefer to retain moisture in smaller areas rather than spreading it over a larger surface, which may lead to localized wetness and possibly decreased thermal comfort. The 100% banana fabric exhibited excellent moisture absorption and wicking qualities, and significantly greater wetted radius. Banana fibers' unique capillary action makes it easier for it to absorb and distribute moisture and hence increased wetted area. This characteristic makes the cloth more thermally comfortable by promoting quick drying and establishing a dry microclimate close to the skin.

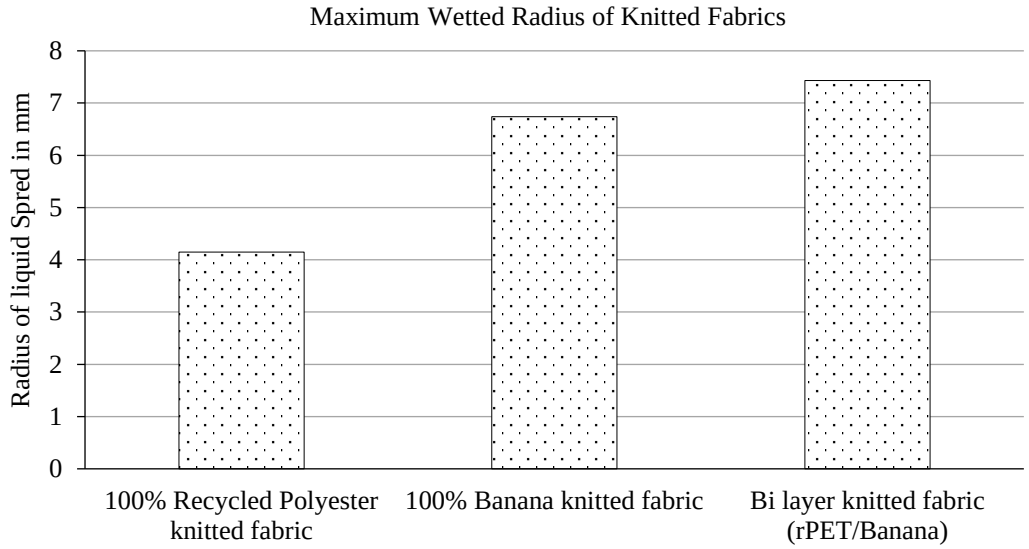

Figure 1. Results of Maximum Wetted Radius of Knitted Fabrics.

Out of the three fabrics produced, the bi-layer knitted fabric showed the largest wetted radius in short time. This clearly shows the moisture management characteristics of both fibres are effectively complemented by the bi-layer structure. While the outside layer of rPET encourages evaporation, the inside layer of banana fibers rapidly absorbs and spreads moisture. For applications demanding high thermal comfort, the bi-layer fabric is appropriate choice because of its large wetted radius, which shows that it can maintain a dry and comfortable microclimate. [23, 24]. This research emphasizes the potential of bi-layer fabric structures which can be effectively used to create high-performance textiles where it combines the advantages of both natural and synthetic fibers.

Measure of Thermal Resistance

Three different knitted fabrics produced were tested for thermal resistance in Figure 2. The ability of a fabric to withstand heat transmission is known as thermal resistance, and it is very essential property for preserving thermal comfort.

In comparison to the other materials, the 100% rPET fabric possessed the lowest thermal resistance, showing that its synthetic nature resulted in less effective insulation, allowing heat to pass through more readily. Although being durable and lightweight, inferior heat resistance of rPET fabric limits their applicability in applications like thermal undergarments or winter garments. Because of banana fiber structure, it can trap air and decrease heat transfer. Hence the 100% banana fabric demonstrated greater thermal resistance which makes it more appropriate choice for applications where thermal comfort is vital.

Out of the three fabrics produced for this investigation, the bi-layer knitted fabric showed the higher degree of thermal resistance. This clearly shows that the bi-layer structure of rPET and banana fibers

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improves the overall thermal insulation and thermal comfort. When the outside layer of rPET improves durability and higher heat resistance, the inner layer of banana fibers offers enhanced insulation. When comparing to single-layer fabrics with the bi-layer fabric, bi-layer fabric offers better insulation because to its improved heat management capabilities.

The combination of rPET (as the outside layer) and banana fibers (as the inside layer) in the bi-layer fabrics can be used in multiple applications such as medical textiles (patient gowns, bedding, and bandages), home textiles (blankets and bed linens), sportswear and active wear (T-shirts and jackets), outdoor clothing (thermal tops and pants), casual clothing (everyday T-shirts, sweaters), thermal underwear, and base layers (worn in cold weather), and more.

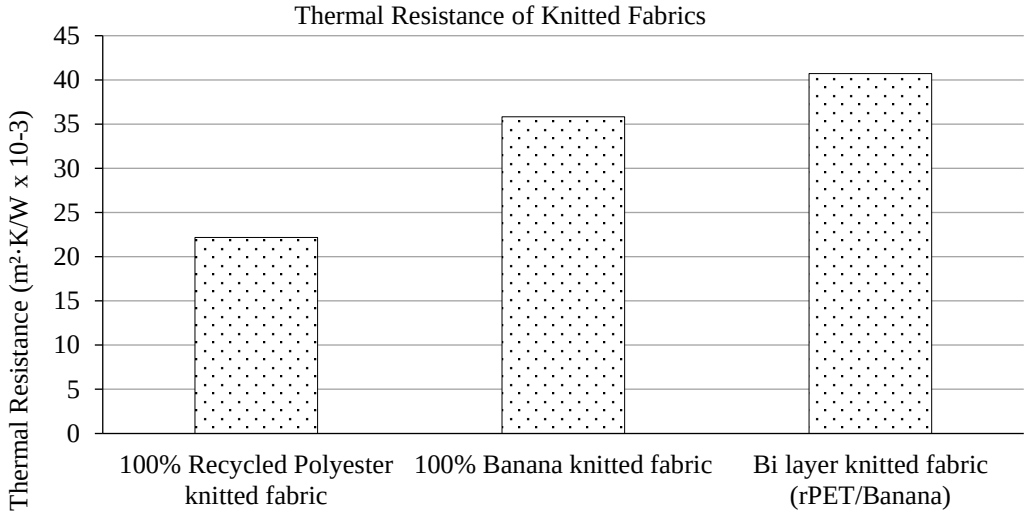

Figure 2. Result of Thermal Resistance of Knitted Fabrics.

CONCLUSION

The study investigated the moisture and thermal comfort properties of recycled polyester fabric, banana fabric and bi-layer knitted fabrics. According to the results obtained, Bi-layer knitted materials have higher thermal resistance (0.040 m²•K/W) which provides better thermal comfort characteristics, which is a vital property required for keeping warm in cold weather. In addition, the bi-layer fabric had the largest maximum wetted radius (7.5 cm), proved the enhanced moisture management property. By combining recycled polyester with banana fibers, it not only meets the high demand of high-performance textiles and functional textiles products and also promotes sustainability. By this study, bi-layer knitted fabrics made of recycled polyester and banana fibers provides the best possible balance of durability, enhanced moisture management, and thermal comfort, making it as an ideal choice for a multiple textile applications.

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