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The Effect of Bamboo Charcoal Micro Particles Application on the Comfort Properties of Woven Fabric

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Abstract

This research delves into bamboo as a sustainable substitute for conventional materials, emphasizing its swift growth and environmental consciousness amid diminishing finite resources. Bamboo charcoal, derived through carbonization, is known for its distinctive qualities, particularly its ability to eliminate microorganisms causing odors and stains in textiles. This study investigates the impact of applying bamboo charcoal microparticles as a coating on woven fabrics, evaluating their influence on comfort qualities and fabric properties. The coating solution, comprising 2% bamboo-derived activated carbon, 2% flexible acrylic binder, 1% wetting agent, and 2000 ml of ionized water, was applied using the pad-dry-cure method. SEM analysis showcased the exceptional durability of bamboo charcoal microparticles on fabric fibers. AATCC Test Method 61-2020 2A, Rapid Sand Washer, and wicking tests assessed the coating's durability, revealing a significant increase in reduction percentages after prolonged washing. This underscores the adverse impact on wicking properties, emphasizing the need for sustainable fabric solutions.

1. Introduction

Bamboo charcoal, a carbonized byproduct, brings forth a myriad of qualities, including homogenous composition, high porosity, and unique functional attributes such as anti-bacterial capabilities, thermal regulation, and odor control. As we venture into the realm of textile applications, we uncover the significant role bamboo charcoal plays in enhancing fabric properties, from moisture absorption to the distribution of perspiration, ensuring wearers remain dry and comfortable [1]. Bamboo charcoal microparticles are gaining attention in the textile industry as a natural alternative to synthetic materials, aligning with the growing demand for eco-friendly products. The focus is on enhancing thermo-physiological comfort qualities, encompassing moisture management, breathability, and heat retention in garments. To assess the potential of bamboo charcoal microparticles for improving fabric comfort, their impact on attributes like wetting, wicking, water vapor permeability, air permeability, and thermal properties of woven fabrics was investigated [2]. While bamboo is not a commonly used coating for textile materials in Malaysia, its emergence as a sustainable alternative makes it a worthwhile subject of study. A previous examination of bamboo charcoal-treated fabrics on cotton showcased promising results, including good washing fastness and durability, with continued improvement in wicking performance even after 20 washes. [3]

This study aims to investigate the physical and surface morphology of bamboo charcoal-coated fabric. Additionally, the research endeavors to evaluate the comfort properties of the bamboo charcoal-coated fabric, specifically focusing on its wicking ability and water vapor transmission rate. By conducting thorough analyses, we aim to gauge the fabric's performance in terms of moisture management and breathability, contributing valuable insights to the understanding of its comfort-related attributes.

2. Method

The process involved fabric coating where the fabric was soaked in a bamboo charcoal solution for 10 minutes before being padded in a paddle mangle (Fig 1) for 5 times to impart coating. The solution was filtered first to ensure no uneven charcoal particles in the solution. The fabric was then dried at 100˚C for 10 minutes before being cured in a Universal Oven at 120˚C for about 4 minutes. The solution for coating bamboo charcoal microparticles were applied to fabrics using the following solution concentrations: bamboo charcoal powder 2 %, flexible acrylic binder 1%, wetting agent 2%, and the liquid material ratio was 1:20. Homogenizer machine was used to stir the solution for 15 minutes at a speed of 2500 rpm. A total volume of 2000 ml of ionized water and a mixed bamboo solution were poured into the solution for 100% cotton fabric, while the same volume was used for the polyester fabric with a mixed polyester solution. The mixture for each solution, containing bamboo charcoal, acrylic binder, and wetting agent, was carefully combined to achieve the desired composition for both fabrics.

The bamboo charcoal was applied to the fabric using a pad-dry-cure procedure. The cloth will be allowed to soak in the particle solution for ten minutes before being run through the paddle mangle. The method was repeated five times for each fabric sample. The fabric was then dried at 100˚C for 10 minutes before being cured in a Universal Oven at 120˚C for about 4 minutes.

Fig 1. *Paddle mangle process*

2.1 Materials

Bamboo charcoal is gaining widespread popularity due to its innovative applications. Produced primarily through pyrolysis, a method involving the thermal breakdown of bamboo at high temperatures in an inert environment, bamboo charcoal is emerging as a revolutionary substance.[4]

Bamboo charcoal microparticles were applied to fabrics using the following solution concentrations: bamboo charcoal powder 2 %, flexible acrylic binder 1%, wetting agent 2%, and the liquid material ratio was 1:20 according to the research.[5] Cotton fabric is a natural fiber derived from the cotton plant's seed hairs. Known for its breathability, comfort, and moisture-absorbing properties, cotton is a popular choice for a variety of clothing and home textiles. It is soft, hypoallergenic, and well-suited for warm weather. Polyester fabric, on the other hand, is a synthetic material made from polymer fibers. It is known for its durability, resistance to wrinkles, and quick-drying properties. Polyester is often chosen for sportswear, outdoor clothing, and items requiring low maintenance.

2.2 Fabric physical test

Fabric weight, thickness, and density were assessed per ASTM D3779-96 standards. Five 110 mm × 110 mm samples were cut from each fabric type using a fabric cutter. Three samples from each fabric type were weighed using an electronic balance, and the average mass reading was recorded.

$$\text{Mass per unit area } (g/m^2) = m/a \quad (1)$$

Thickness is one of the factors that could affect the thermal and water vapour transmission performance on fabric. In this research, the thickness was measured by fabric thickness gauge according to ASTM D1777-96. Thickness for each sample was measured five times for average. Fabric density is the combination of warp density and weft density. The total numbers of warp and weft yarn in 1 inch was measured 5 times and the average was calculated.

2.3 Scanning electron microscopy (SEM)

The SEM image analysis was done to study the surface morphology of the bamboo charcoal coated fabric compared to uncoated fabric. Before using the SEM, a 1cm x 1cm sample of each of the two fabrics must be divided into two groups: uncoated, coated. The Quorum Q 150R S coating apparatus then applied a layer of gold to the specimen. At a magnification of X1000, the surface morphology of each of the samples was analyzed. This is since at magnification X1000, the surface morphology of the sample can be observed more clearly than at magnification X500. COXEM EM-30AX was used for the SEM analysis of uncoated and coated fabrics.

2.4 Durability of coating finishes

Coating durability was evaluated through repeated wash cycles using AATCC Test Method 61-2020 2A with a Rapid Sand Washer (Fig.2). Fabric samples, taken from each material, underwent washing in a solution containing detergent powder and steel balls for mechanical agitation. After washing, rinsing, and drying, samples were tested for warp-way wicking property to gauge durability after 2 and 4 laundering cycles, simulating home machine laundering.

Fig 2. *Rapid sand washer*

2.5 Fabric wicking area

Three sets of fabric samples, each measuring 30 cm × 2.5 cm, were cut for testing according to the National Chinese Standard FZ/T01071-2008. The samples were vertically fixed with one end immersed in distilled water. Over a 30-minute period, water height along the sample was measured every 5 minutes, and the average water transfer height was determined. This test assessed the fabrics' wicking ability, revealing their total water transport capacity.

Wicking area (cm^2) = c × d (2)

2.6 Water vapour transmission rate (WVTR)

The test was carried out in accordance with ASTM E96-95, also known as the "traditional wet cup test". The fabrics was categorised into three distinct sets. The specimens were trimmed to dimensions of $12cm^2$. The samples were precisely fitted to the cup's size. Subsequently, the cup will be fill with distilled water, leaving a 0.5-inch space. The narrow interstice denotes the gaseous medium that separates the specimens from the water phase. The specimens were affixed to the receptacle and subsequently secured to avert dissipation to the environment, thereby guaranteeing that the sole dissipation of vapours occurred through the specimen. The weight of the cup containing water and sample was measured using an electronic balance during the initial assembly. The weight of the assembled object will be measured hourly until a linear trend will be observed in the results.

$$\text{WVTR} = \frac{24 \times \Delta m}{a \times t} \quad (3)$$

3. Result

SEM analysis for uncoated and coated 100% cotton and 100% polyester fabric. Fig 3 demonstrates the enduring adherence of bamboo charcoal microparticles to the fibers of both fabric samples, showcasing the remarkable durability of bamboo charcoal as the chosen raw material in this study. The sustained attachment underscores the material's resilience, contributing to the longevity and effectiveness of the treated fabrics. This observation emphasizes the potential of bamboo charcoal as a durable and effective additive for enhancing the characteristics of textile materials.

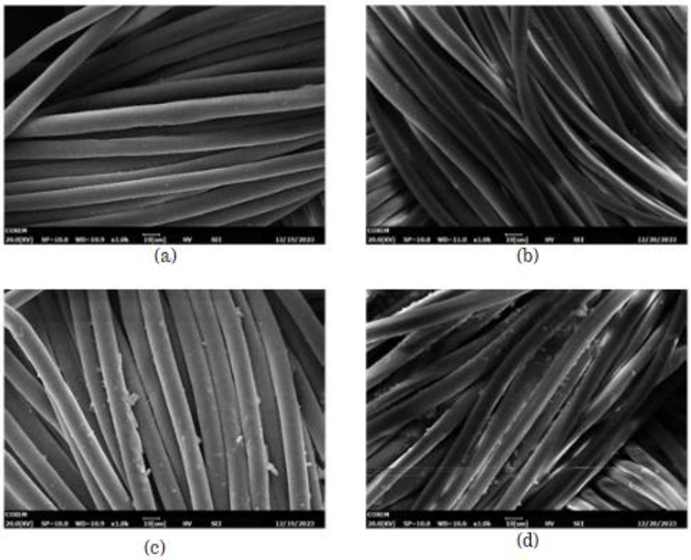


Fig 3. *SEM analysis (a)uncoated cotton (b)uncoated polyester (c)coated cotton (d)coated polyester*

Table 1 displays the weight, thickness, and density of 100% cotton and 100% polyester fabrics, while Table 2 presents the results of sample thickness and fabric weight after coating. The coated cotton fabric, with a weight of 100.00 grams per $1m^2$, is slightly heavier than the uncoated cotton at 95.76 grams (an increase of approximately 4.42%). However, the coated cotton fabric is slightly thinner, measuring 0.206mm compared to the uncoated cotton's 0.212mm (a decrease of 2.83%). For polyester, the coated fabric is approximately 2.85% heavier than the uncoated counterpart, with weights of 98.43 grams and 95.70 grams per $1m^2$, respectively. The coated polyester is also slightly thinner at 0.198mm compared to the uncoated polyester's 0.200mm, representing a 1% reduction in thickness.

Table 1 *Physical test of fabric in terms of weight, thickness, and density*

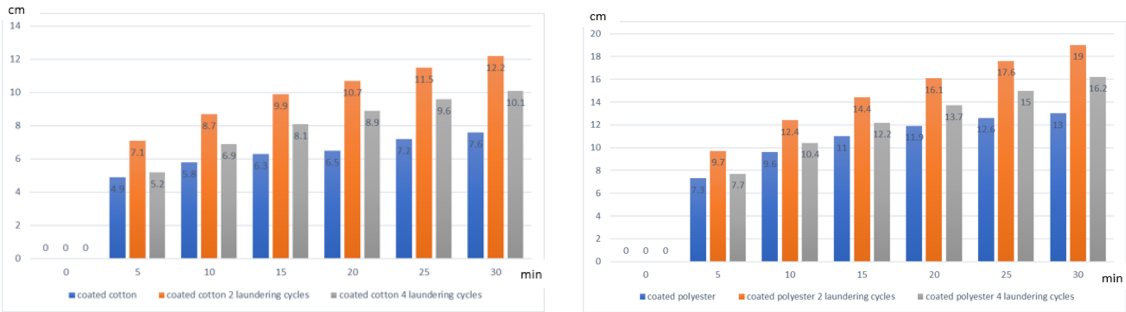
Fabrics	Ends/inch	Picks/inch	Areal density (y/inch)	Fabric thickness (mm)
100% cotton (uncoated)	113	69	182	0.212
100% polyester (uncoated)	107	85	192	0.200

Table 2 *Mass per unit area and thickness of fabric samples for uncoated and coated fabrics*

Fabrics	Mass per unit area (g/m^2)	Thickness (mm)
Uncoated cotton	95.76	0.212
Uncoated polyester	95.70	0.200
Coated cotton	100.00	0.206
Coated polyester	98.43	0.198

3.1 Durability of the fabric test

The analysis of wicking reduction in coated cotton and polyester fabrics after 10 and 20 washing cycles reveals significant trends. Coated cotton shows an increase in reduction from 25% after 2 laundering cycles to 29.41% after 4 cycles, suggesting a cumulative impact on wicking ability with prolonged washing (Fig 4). Coated polyester fabric exhibits a more pronounced escalation in reduction, rising from 25.93% after 2 laundering cycles to 33.33% after 4 cycles (Fig 4). This substantial increase in reduction percentages for both fabrics indicates that extended washing exacerbates the negative impact on wicking properties. Factors influencing this increase may include coating-related changes, wear and tear, or alterations in the fabric's structure over successive washing cycles. This analysis underscores the importance of considering the long-term effects of washing on coated fabrics, emphasizing the need for further investigation into the specific mechanisms driving these observed trends. A comparison of wicking test for unwashed and washed coated fabric were shown in (Fig 4).



(a) (b)

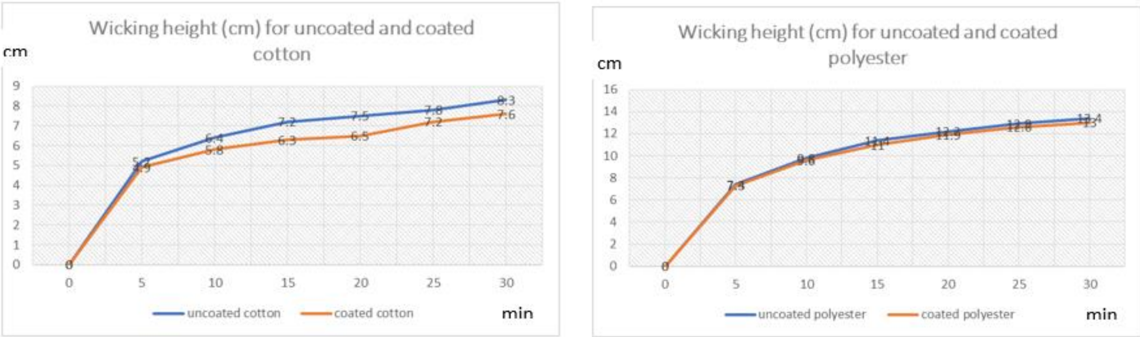
Fig 4. *Durability of the fabric test (a)coated cotton (b)coated polyester*

3.2 Fabric wicking test

Table 3 displays wetting height results for uncoated and coated fabrics. In the wicking test, uncoated cotton had a wetting height of 5.2 cm, reduced to 4.9 cm for coated cotton in the first 5 minutes, showing a 6.12% decrease. Uncoated polyester had a wetting height of 7.4 cm, reduced to 7.3 cm for coated polyester, indicating a subtle 1.37% decrease. The analysis suggests a positive influence of the coating on both fabrics, improving wicking properties, and highlighting potential enhanced performance in specific applications. A comparison between coated and uncoated fabrics for wicking was conducted to observe the water transport height differences every 5 minutes. In the wicking test, the uncoated fabric showed a higher water transport capability, evidenced by a greater wetting height compared to the coated fabric (fig 5). The coated fabric exhibited superior water management capabilities, displaying a lower wetting height than the uncoated fabric. This suggests that the applied coating effectively enhances the fabric's wicking performance, leading to a more efficient transport of water.

Table 3 *Wetting height in centimetre for uncoated and coated fabrics*

S No.	Fabric type	Uncoated fabric (cm)	Coated fabric (cm)	Reduction in wetting height (cm)	% decrease of wetting height
1	100% cotton	5.2	4.9	0.3	6.12
2	100% polyester	7.4	7.3	0.1	1.37



(a) (b)

Fig 5. *Wicking height (a)cotton fabric (b)polyester fabric*

3.3 Water vapour transmission rate (WVTR)

The average water vapor permeability values for the examined fabrics are presented in Table 4. Observations indicate that the coated fabrics demonstrate a notable enhancement in water vapor permeability.

The improvement was 473.33 g/m^2/day, 456.67 g/m^2/day and 483.33 g/m^2/day for coated 100% cotton fabric. The increase of water vapour for coated cotton fabric was 1.43%, 1.48% and 3.57% respectively. The improvement for coated polyester was 443.33 g/m^2/day, 483.33 g/m^2/day and 450.00 g/m^2/day. The increase of water vapour for coated polyester was 10.83%, 18.84% and 8% respectively. The large specific surface area and porous structure of bamboo charcoal may aid the treated cloth in absorbing water vapour and fast releasing it into the atmosphere.

Table 4 *Water vapour permeability of uncoated and coated fabrics*

S. No.	Fabric type	Uncoated sample (g/m^2/day)	Coated sample (g/m^2/day)
1	100% cotton	466.67	473.33
		450.00	456.67
		466.67	483.33
2	100% polyester	400.00	443.33
		406.67	483.33
		416.67	450.00

4. Conclusion

In conclusion, the SEM analysis demonstrates the excellent durability of bamboo charcoal microparticles, showcasing their sustained adherence to the fibres of both fabric samples. This resilience emphasizes bamboo charcoal's potential as a durable and effective additive, contributing to the longevity and effectiveness of treated fabrics. The untreated sample serves as a valuable basis for comparison, revealing the natural arrangement of cotton and polyester fibres. These findings underscore the promising role of bamboo charcoal in enhancing textile material characteristics. The observed properties highlight the potential for its application in the textile industry as a sustainable and enduring solution. Further exploration and utilization of bamboo charcoal in fabric treatments could pave the way for improved and eco-friendly textile materials. Furthermore, this comprehensive study has investigated the wicking reduction in coated cotton and polyester fabrics after 10 and 20 washing cycles. The findings reveal significant trends, with coated cotton fabric exhibiting a cumulative impact on wicking ability and coated polyester fabric demonstrating a more pronounced escalation over successive laundering cycles. The notable increase in reduction percentages for both fabrics emphasizes the importance of considering the long-term effects of washing on coated fabrics. Factors contributing to this increase may include cumulative coating-related changes, wear and tear, or alterations in fabric structure. This underscores the necessity for further research to elucidate the specific mechanisms driving these observed trends. Additionally, the comparison of wicking test results across various samples underscores the need for a nuanced understanding and optimization of coated fabrics for real-world applications. The insights gained from this study contribute to advancing our knowledge of the durability and performance of coated textiles, particularly in the context of wicking properties, offering valuable considerations for future research and development in textile science and technology.

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This guide contains examples of common types of APA Style references. Section numbers indicate where to find the examples in the Publication Manual of the American Psychological Association (7th ed.).

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