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COMPARISON OF ANTIBACTERIAL AND SOME PHYSICAL PROPERTIES OF KNITTED FABRICS PRODUCED FROM BAMBOO, COTTON AND VISCOSE FIBER

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ABSTRACT: Bamboo, being a regenerated cellulosic fiber, has gained popularity in the industry due to its ecological properties. Fabrics made from bamboo exhibit comfort, wrinkle resistance, and thermal regulation. Additionally, they possess natural antibacterial, hypoallergenic, and biodegradable properties, along with high moisture absorption, shine, softness, and UV protection. The study compared knitted fabrics from these fibers, evaluating their water vapor permeability, air permeability, burst strength, water absorbency, abrasion resistance, and antibacterial properties according to international standards. Results showed that bamboo and cotton fibers have similar water vapor permeability, both higher than viscose fibers. Bamboo fiber's air permeability is notably higher than cotton and viscose fibers. Moreover, bamboo's water absorption surpasses cotton and viscose, leading to better sweat absorption. Bamboo fiber demonstrates superior antibacterial properties, with a bacterial eradication rate of 44.17%, surpassing both cotton 33.33% and viscose fibers 25%.Bamboo fiber demonstrated superior antibacterial properties compared to cotton and viscose, with higher bacterial eradication rates. Fabrics made from bamboo exhibited higher bursting strength and comparable pilling values to cotton, outperforming viscose. Overall, bamboo fiber demonstrated better air permeability, water absorbency, antibacterial properties, abrasion resistance, and bursting strength compared to cotton and viscose, making it a desirable choice for cool and comfortable textiles.

Keywords: Bamboo, Viscose, Cotton, Physical properties, Antibacterial activity

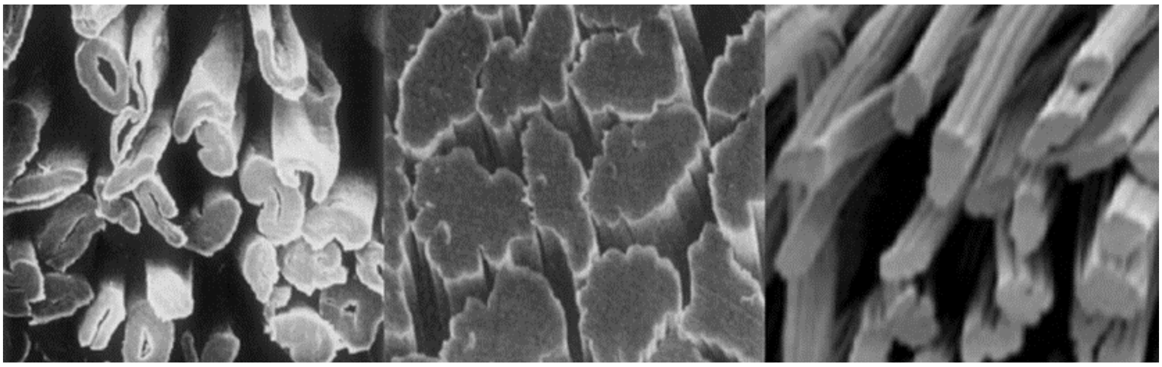
1. INTRODUCTION

The necessity for clothing remains one of the fundamental needs worldwide, evolving alongside advancements in industry and science. Initially centered on providing mere coverage and protection, the spectrum of clothing preferences has expanded to encompass various activities such as sports, work, and leisure, with an increasing emphasis on comfort, health, and environmental consciousness. In this regard, the utilization of natural and blended fibers has gained prominence over synthetic alternatives like polyester and polyamide, with materials such as cotton and linen becoming preferred choices [1].

Bamboo fiber, among the natural and cellulosic fibers, has garnered attention in the textile industry primarily for its antibacterial properties, commonly employed in the production of socks [2]. However, its array of attributes, including a cooling sensation and remarkable softness, outshine other fibers in terms of comfort and health benefits. These comfort properties make it particularly suitable for activewear, ensuring ease of movement during physical activities. Various studies have investigated the thermal comfort properties of fabrics knitted from bamboo/cotton blended yarns, comparing them with fabrics of different structures and raw materials. For instance, research has shown that air permeability values of Lacoste bamboo/cotton blended fabrics exceed those of single jersey and rib fabrics. Moreover, studies have revealed that as the bamboo fiber ratio increases, thermal conductivity decreases, while water vapor and air permeability increase. Furthermore, bamboo fiber's natural antibacterial and deodorizing properties make it increasingly appealing in the context of hygiene-conscious consumers. Its efficacy in eliminating odor and inhibiting bacterial and fungal growth, even after repeated washes, underscores its suitability for antimicrobial textiles. Additionally, bamboo fabric's insulating properties offer wearers comfort in varying climates, maintaining coolness in summer and warmth in winter. In comparison to cotton and other cellulosic fibers, bamboo boasts advantages such as superior moisture absorption, drapability, softness, cooling effect, and spinning capacity [3,4]. These qualities, coupled with its eco-friendliness, position bamboo fiber as a promising contender in the textile industry.

Majumdar et al. compared the thermal properties of different knitted fabric structures (plain, rib and interlock) produced from cotton, bamboo and cotton-bamboo blended yarns. Three yarn counts and three fiber blends (100% cotton, 100% bamboo and 50:50 cotton: bamboo) were used. It was determined that the thermal conductivity decreased as the bamboo fiber ratio increased. Thermal conductivity was found to be lower for fabrics made from finer yarns. Air permeability and water vapor permeability increased with increasing bamboo fiber content [5]. Chidambaram et al. investigated the thermal comfort properties of knitted fabric structures made of regenerated bamboo, cotton and cotton-bamboo blended yarns. It was found that the thermal conductivity of the fabrics decreased with the increase of the bamboo fiber content. It was stated that the water vapor permeability and air permeability of the fabrics increased with the increase of the bamboo fiber ratio [6]. Aruchamy et al. investigated the thermal comfort properties of cotton, bamboo and cotton: bamboo (50:50, 70:30, 30:70) blended yarns/fabrics. It was determined that the thermal conductivity of the blended fabrics decreased with the increase of the bamboo fiber ratio [7] .

Many studies were carried out on the thermophysiological comfort properties of yarn and fabrics in relation to fiber characteristics and fabric structural parameters [8-17]. Microorganisms can quickly reproduce on textile surfaces under the influence of moisture, nutrients and temperature. Unwanted odors and stains may occur on textile surfaces due to the growth of microorganisms. In addition, color change, decrease in strength and increase in pollution can be observed on the textile surface [18-19]. In recent years, with the increase in people's hygiene awareness and sensitivity, the tendency towards antimicrobial textiles has increased. It is estimated that the use of antibacterial textile products will increase the sales price of textile products [20]. Bamboo fiber has natural antibacterial and deodorizing properties: It eliminates odor naturally and has effective antibacterial properties against the formation of bacteria and fungi. Its natural antibacterial properties help reduce bacteria that grow on bamboo clothes and cause unpleasant odors, even after multiple washes. Additionally, bamboo fabric has insulating properties. The micro-holes and cavities in the cross-section of the bamboo fiber give it the ability to breathe and keep cool. Compared to bamboo, cotton and other cellulosic fibres, it has advantages such as high moisture absorption ability, drapeability, soft handle, cool keeping feature and good spinning capacity [21]. SEM images showcasing bamboo, viscose, and cotton fibers are provided in Figure 1.



(a) (b) (c)

Figure 1. SEM images of cotton, viscose and bamboo fiber (a)-Cotton fiber, (b)-Viscose fiber, (c)-bamboo fiber [16]

Bamboo fiber is a natural material that holds significant potential in the textile industry due to its unique properties. Its structure sets it apart from other natural lignocellulosic fibers, making it highly desirable [22]. In recent years, there has been growing interest in bamboo fibers as renewable biomass materials for textiles [23] and composite reinforcement [24]. When utilized in textiles, bamboo fibers exhibit numerous exceptional properties, including high strength, resistance to bacteria, excellent thermal conductivity, and superior water and sweat absorption [25, 26].

The aim of this study is to highlight the natural antibacterial properties of bamboo fiber, its cooling and softness characteristics, and its immediate sweat absorption capabilities. Moreover, it aims to demonstrate that these properties surpass those of other natural and cellulosic fibers, advocating for its widespread adoption in sports and everyday clothing. Assessments of clothing comfort hinge on factors such as water absorption, thermal permeability, and air permeability in fabrics. Additionally, the wearers' metabolic rate, perceptual differences, and psychological state also play pivotal roles in clothing comfort. Thus, this study objectively evaluates the comfort of bamboo fiber by scrutinizing the performance properties of fabrics produced from various raw materials, employing internationally recognized testing standards.

2. MATERIAL AND METHODS

2.1.Material

Bamboo, cotton and viscose ring spun yarns of Ne 30/1 were employed to produce 2-yarn fleece knitted fabrics, commonly utilized in outdoor garments. The knitting process was conducted using an E 22 Mayer circular knitting machine with 32 feeders. Each fabric variant was knitted with identical course (12 courses/cm) and wale count (14 wales/cm). The technical specifications of the 2-yarn fleece fabrics are presented in Table 1.

Table 1. Knitted fabric properties

Knitted fabric code	Knitted fabric type	Composition (%)	Yarn Count	Fabric Weight (g/m^2)	Thickness (mm)
Bamboo-Elastane (B)	2-yarn fleece	95% Bamboo %5 elastane	Ne 30 (22 dtex elastane)	250	1.19
Cotton-Elastane (C)	2-yarn fleece	95% Cotton %5 elastane	Ne 30 (22 dtex elastane)	250	1.21
Viscon-Elastane (V)	2-yarn fleece	95% Viscon %5 elastane	Ne 30 (22 dtex elastane)	250	1.18

The fabrics manufactured from these yarns were also knitted on the Meyer brand knitting machine at Linoteks Textile Knitting Industry. Specifically, a 32-pus 28-fein machine was utilized for the knitting process. All fabrics were produced with the same density and contained 5% elastane. Subsequent to the manufacturing process, fabric samples were conditioned for 24 hours under standard atmospheric conditions, maintained at 20±2 °C temperature and 65±4% relative humidity.

2.2.Method

During the studies, the same tests were applied to 3 different fabrics with different properties in the same environment for objective measurements and evaluations. All tests were performed on fabrics under laboratory conditions for 24 hours. Fabrics were tested in international test laboratories; Heat and Water Vapor Permeability (SGS Test Laboratory), Air Permeability (Intertek Test Laboratory), Water Absorbency (Bureau Veritas Test Laboratory), Anti-insulation Determination (Bureau Veritas Test Laboratory), Blasting Strength (Denge Chemistry and Textile), Peeling (Denge Chemistry and Textile) tests were carried out.

Fabric samples underwent testing at international test laboratories for various properties:

Air Permeability: Tested at Intertek Test Laboratory according to ISO 9237:1995 standard. Air permeability is vital for evaluating comfort parameters. The test was conducted at 20±2 °C and 65±4% humidity using an SDL Atlas Digital Air Permeability Tester Model M021A under 100 Pa air pressure per 20 cm2 fabric surface. Measurements were averaged from 10 different areas of fabrics [27].

Water Vapor Permeability: Conducted at SGS Test Laboratory according to BS 7209:1990 standard. The test measures the fabric's ability to transfer water vapor and is crucial for assessing comfort, especially in hot weather or active sports. The test involved placing 46 ml of water in a dish with an 83 mm internal diameter. After rotating the turntable for 24 hours, the water vapor loss through the fabrics was determined. The measurement was repeated three times for each fabric, and the average of three tests was taken [28-29].

Abrasion Resistance and Pilling: Tested using an ICI BOX PILLING test device and Martindale tester according to BS EN ISO 12945-1 standard. The fabrics were subjected to 14000 cycles, and pilling was evaluated on a scale of 1 to 5, where 1 indicates the highest pilling tendency. These tests were conducted objectively on three different fabrics with varying properties in the same environment to ensure accurate and reliable measurements. The results were recorded as the average of two separate counts for each property [30].

Water Absorption: Carried out at Bureau Veritas Test Laboratory according to AATCC 79-14 standard. This test measures the time it takes for a drop of water placed on the fabric surface to be completely absorbed. The time until complete absorption was recorded for each fabric sample. Antibacterial Determination: Conducted at Bureau Veritas Test Laboratory according to AATCC 100-2012 standard and BS EN ISO 13938-2 standard. The test evaluates the antibacterial properties of the fabric. A bacterium culture was applied to each specimen, incubated, and surviving colonies were counted [31].

Burst Strength: This test was applied to the produced sample fabrics in a Truburst James H.Heal brand test device according to BS EN ISO 13938-2 standard. The mean value of five measurements per each fabric type were recorded for knitted fabrics. [32-34].

Antibacterial Activity: This properties was evaluated according to antibacterial standard AATCC Test method 100-2012. A maximum of 150 CFU were transferred to each plate. The inoculated plates were incubated at 37 °C for at least 24 h and surviving colonies were counted [35, 36]. The results were the average of two separate counting.

3. RESULTS AND DISCUSSIONS

3.1. Water Vapor Permeability Test Measurement Results and Evaluations

The results of the water vapor permeability test performed in accordance with the BS 7209: 1990 standard in the SGS Test Laboratory are presented in Table 1.

Table 1. Water vapor Permeability Test Measurement Results of Produced Fabrics

Fabric code	Test results (%)
B	99.5
C	97.7
V	86.2

According to the findings presented in Table 1, the water vapor permeability values of cotton and bamboo fibers are closely comparable and higher than those of viscose fiber. This suggests that cotton exhibits the highest resistance to sweating, followed by bamboo fiber, while viscose fiber shows the lowest performance in this regard. Both cotton and bamboo fibers offer a notably cool sensation in fabrics and garments compared to viscose fiber.

The results highlight that cotton and bamboo fibers possess desirable cooling and sweat-evacuation properties, particularly crucial for sportswear. Despite their close similarity, garments made from fabrics containing cotton fiber are more prevalent in the market. However, with the demonstrated performance of bamboo fiber fabrics in this test, there is a promising opportunity for the widespread adoption of clothing made from bamboo fiber fabrics.

3.2. Air Permeability Test Measurement Results and Evaluations

Air permeability test results of fabrics according to ISO 9237 standard in Intertek Test Laboratory are presented in Table 2.

Table 2. Air Permeability Test Measurement Results of Produced Fabrics (100 Pa 20 cm^2)

Test results	B	C	V
Average	380 mm/s	172 mm/s	119 mm/s

Table 2 reveals that the air permeability values of bamboo fiber are approximately 2.2 times higher than those of cotton fiber and nearly 3.3 times higher than those of viscose fiber. These findings indicate that bamboo fiber exhibits superior air permeability compared to both cotton and viscose fibers. Consequently, fabrics produced from bamboo fiber offer a heightened sensation of coolness relative to fabrics made from cotton and viscose.

The test results underscore that bamboo fiber is particularly well-suited for sportswear, as it provides a superior cooling sensation compared to cotton and viscose. Therefore, incorporating bamboo fiber into sportswear designs holds significant potential for enhancing wearer comfort and performance.

3.3.Water Absorption Test Measurement Results and Evaluations

Water absorbency test results of fabrics according to AATCC 79-14 standard in Bureau Veritas Test Laboratory are presented in Table 3.

Table 3. Water Absorption Test Results

Fabric code	Test results (%)
B	24
C	15
V	1

As depicted in Table 3, bamboo fiber exhibits higher water absorption compared to both cotton and viscose fiber. Consequently, fabrics crafted from bamboo fiber tend to retain more sweat than those made from cotton and viscose fibers. Fabrics with high sweat retention rates offer reduced sensations of wetness and diminished adherence to the skin. Therefore, expanding the utilization of bamboo fiber in this domain is advantageous, as it furnishes desirable comfort attributes for sportswear, such as reduced wet sensation, sweat absorption, and skin non-adhesiveness.

3.4. Antibacterial Activity Detection Test Measurement Results and Evaluations

The test results of the antibacterial determination of fabrics according to the AATCC 100-2012 standard in Bureau Veritas Test Laboratory are presented in Table 4.

Table 4. Antibacterial Test Measurement Results of Bamboo Fiber

Results	**B**	**C**	**V**
Inoculum concentration (cFu/ml)	1.3x10000	1.3x10000	1.3x10000
Bacterial value (ATCC)(cFu/4,8 cm diameter/4 number)	0. hour value =1.1x10000 24. hour value =5.0x 100	0. hour value =1.1x10000 24. hour value =1.0x 100	0. hour value =1.2x10000 24. hour value =1.0x 100
Reduction percentage	%99,55	%99,91	%99,92
Inoculum concentration (cFu/ml)	1.2x10000	1.2x10000	1.2x10000
Bacterial value (ATCC)(cFu/4,8 cm diameter/4 number)	0. hour value =1.2x10000 24 hour value =5.3x10000	0. hour value =1.2x10000 24 hour value =4.0x10000	0. hour value =1.2x10000 24. hour value =3.0x10000
Reduction percentage	%55,83	%66,67	%75.00

As indicated in Table 4, bamboo fiber demonstrates a bacterial extinction rate of 44.17%, while cotton fiber exhibits a rate of 33.33%, and viscose fiber registers at 25%. These findings underscore the superior antibacterial properties of bamboo fiber compared to both cotton and viscose fibers. Moreover, these results highlight the ecological superiority of bamboo fiber over its counterparts.

Given its heightened antibacterial properties, bamboo fiber also possesses greater anti-allergic characteristics compared to cotton and viscose fibers. With its ecological and hypoallergenic qualities, bamboo fiber warrants wider adoption in sportswear compared to other fibers.

3.5. Burst Strength Results

Burst strength test was applied to the produced sample fabrics in a Truburst James H.Heal brand test device according to BS EN ISO 13938-2 standard. The burst strength results of the fabrics used as a result of the trials are presented in Table 5.

Table 5. Burst Strength Results

Test results	**B**	**C**	**V**
Average	413 kPa	408 kPa	408 kPa

As seen in Table 5., bursting strength of fabrics produced from bamboo fiber; It is higher than fabrics produced from viscose and cotton fiber.

3.6. Abrasion Resistance and Pilling Test Results

The pilling test of the fabrics was carried out in the "ICI BOX PILLING" test device according to the BS EN ISO 12945-1 standard. The pilling values of the tested fabrics are presented in Table 6.

Table 6. Abrasion Resistance and **Pilling** Test Results

Test results	**B**	**C**	**V**
Average	4/5	4/5	1/2

As can be seen in Table 6, it has been determined that the pilling values of the fabrics produced from cotton and bamboo fibers are close to each other and higher than the fabrics produced from viscose fiber.

4. CONCLUSIONS

This study aims to promote the utilization of bamboo fiber in sportswear by accentuating its cooling sensation, sweat absorption, and antibacterial properties. The test results we conducted for this purpose have yielded positive outcomes.

The significantly higher air permeability of bamboo fiber, being 2.2 times greater than cotton and 3.2 times greater than viscose, underscores its ability to impart a refreshing sensation and ensure comfortable movement in sportswear. Moreover, bamboo fiber's superior water-absorbing capacity, surpassing that of cotton and viscose fibers, indicates its efficacy in trapping and dissipating sweat, thereby facilitating unhindered movement without skin adherence. Although bamboo fiber's water vapor permeability closely resembles that of cotton fiber, its enhanced air permeability ensures greater comfort compared to both cotton and viscose fibers, rendering it more suitable for sportswear applications.

Furthermore, the test results affirm the superior antibacterial properties of bamboo fiber compared to cotton and viscose fibers, affirming its suitability for clothing from a health perspective. Additionally, bamboo fiber's inherent silky softness, devoid of chemical additives, and its ability to enhance fabric drape make it more conducive to ease of movement in sportswear compared to fabrics produced from cotton and viscose fibers. Unlike cotton and viscose fibers, which often require additional silicone treatments to achieve softness, bamboo fiber naturally provides this attribute. Moreover, bamboo fiber's UV ray-blocking capability renders it more advantageous for use in sportswear compared to cotton and viscose fibers.

A comprehensive comparison of our results is presented in Table 7, highlighting bamboo fiber's superiority across various parameters relevant to sportswear.

Table 7. Comparison of the Properties of Fabrics Produced from Bamboo, Cotton and Viscose Fibers

Properties of Fabric	B	C	V
Water vapor permeability	%97.7	%99.9	%86.2
Air permeability (100 Pa 20 cm^2) (mm/s)	380	172	119
Water absorbency	24	15	1
Bacteria destruction rate	%44.17	%33.33	%25
Abrasion resistance	4/5	4/5	1/2
Bursting strength (kPa)	413	408	408

As evidenced in Table 7, bamboo fiber consistently outperforms cotton and viscose fibers across various parameters relevant to sportswear. Specifically, bamboo fiber exhibits superior air permeability, water absorbency, antibacterial properties, abrasion resistance, and bursting strength compared to both cotton and viscose fibers.

The air permeability values of bamboo fiber are notably higher, being 2.2 times greater than cotton fiber and 3.2 times greater than viscose fiber. This indicates that bamboo fiber allows for better air circulation, enhancing the wearer's comfort during physical activities. Additionally, bamboo fiber's higher water absorbency translates to improved sweat absorption and reduced moisture retention compared to cotton and viscose fibers.

Furthermore, bamboo fiber demonstrates superior antibacterial properties, with a bacterial eradication rate of 44.17%, surpassing both cotton (33.33%) and viscose fibers (25%). This highlights bamboo fiber's ability to inhibit bacterial growth and minimize odor formation, contributing to a fresher and more hygienic sportswear experience.

Moreover, fabrics made from bamboo fiber exhibit higher bursting strength and comparable pilling values to those made from cotton, indicating better durability and resistance to wear and tear.

Overall, the objective tests conducted in this study affirm that fabrics containing bamboo fiber are more suitable for use in sportswear compared to those containing cotton and viscose fibers.

References

[1] Karakan G., (2009). Teknik Tekstillerin Koruyucu Yapılarda Kullanımı. *Tekstil Teknolojileri Elektronik Dergisi,* Cilt: 3, No: 1, 65-70.
[2] Avcı, H., (2007). Yeni Liflerden Mamul Çorapların Konfor Özellikleri. İstanbul Teknik Üniversitesi, Fen bilimleri Enstitüsü, Yüksek lisans tezi, İstanbul.
[3] Özgüney A. T., (2016). Investigating The Effects Of Different Softeners on Pilling Properties And Durability to Washing of Bamboo Knitted Fabrics. *Tekstil ve Konfeksiyon Dergisi,* Cilt: 26, Sayı: 3, 307 – 313.
[4] Türksoy, H. G., Üstüntağ, S. & Çarkıt, G. (2017). Bambu/Pamuk Karışımlı İpliklerden Örülen Kumaşların Termal Konfor Özellikleri. *Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi*, 19 (56), 510-518.
[5] Majumdar, A., Mukhopadhyay, S., & Yadav, R. (2010). Thermal properties of knitted fabrics made from cotton and regenerated bamboo cellulosic fibres. *International Journal of Thermal Sciences*, 49(10), 2042-2048.
[6] Chidambaram, P., Govindan, R., & Venkatraman, K. C. (2012). Study of thermal comfort properties of cotton/regenerated bamboo knitted fabrics. *African Journal of Basic & Applied Sciences,* 4(2), 60-66.
[7] Aruchamy, K., Subramani, S. P., Palaniappan, S. K., Pal, S. K., Mylsamy, B., & Chinnasamy, V. (2022). Effect of blend ratio on the thermal comfort characteristics of cotton/bamboo blended fabrics. *Journal of Natural Fibers*, 19(1), 105-114.
[8] Kim, H. A. (2017). Physical properties of ring, compact, and air vortex yarns made of PTT/wool/modal and wearing comfort of their knitted fabrics for high emotional garments. *The Journal of the Textile Institute*, 108(9), 1647–1656.
[9] Saricam, C., & Kalaoglu, F. (2014). Investigation of the wicking and drying behaviour of polyester woven fabrics. *Fibers & Textiles in Eastern Europe*, 22(3), 73–78.
[10]Tashkandi, S., Wang, L., & Kanesalingam, S. (2013). An investigation of thermal comfort properties of Abaya woven fabrics. *Journal of the Textile Institute,* 104(8), 830–837.
[11] Varshney, R. K., Kothari, V. K., & Dhamija, S. (2010). A study on thermophysiological comfort properties of fabrics in relation to constituent fiber fineness and cross-sectional shapes. *Journal of the Textile Institute,* 101(6), 495–505.
[12] Karakan G., Abdulla, G., & Kodaloğlu, M. (2010). Murata vortex iplik yapısında merkez ve sargı liflerinin incelenmesi. *Tekstil Teknolojileri Elektronik Dergisi,* 4(3),9-19.
[13] Vimal, J. T., Murugan, R., & Subramaniam, V. (2016). Effect of weave parameters on the air resistance of woven fabrics. *Fibers & Textiles in Eastern Europe, 24*(1), 67–72.
[14] Çeven E.K, Karakan Günaydin G. (2018). Investigation of Moisture Management and Air Permeability Properties of Fabrics with Linen and Linen-Polyester Blend Yarns. *Fibers & Textiles in Eastern Europe* 2018; 26, 4(130): 39-47. DOI:10.5604/01.3001.0012.1311.

[15] Karakan G., Abdulla, G., & Kodaloğlu, M., (2009). Murata vortex iplik eğirme sistemi ve iplik özelliklerinin incelenmesi. *Tekstil Teknolojileri Elektronik Dergisi,* 3(3), 47-55.
[16]Kodaloğlu, M., & Karakan Günaydın, G. (2021). Çözgülü örme işletmesinde toz maruziyet ölçümlerinin iş sağlığı ve güvenliği açısından değerlendirilmesi. *International Journal of Engineering and Innovative Research,* 3(1), 1-11.
[17]Kodaloğlu, F. A., & Kodaloğlu, M. (2023). Determining the drying rates of fabrics with different knit structures by fuzzy logic method. *International Journal of Computational and Experimental Science and Engineering,* 9(2), 191-196.
[18] Arık, B.,(2013). Kitosanın Farklı Aplikasyon Yöntemleri Uygulanarak Medikal Tekstillerde Kullanılabilirliğinin Araştırılması. Ege Üniversitesi, Fen Bilimleri Enstitüsü, Doktora Tezi, 236s, İzmir.
[19] Tutak, M., & Gün, F. (2011). Antimicrobial effect of CI Basic Red 18: 1 and CI Basic Yellow 51 on some pathogenic bacteria. *Fibers and Polymers,* 12(4), 457-460.
[20] Büyükakıncı, Y. (2009). Bambu Elyafının Özelliklerinin İncelenmesi. Marmara Üniversitesi, Fen Bilimleri Enstitüsü, Doktora Tezi, İstanbul.
[21] Liu, Y., Hu, H., (2008). X-ray diffraction study of bamboo fibers treated with NaOH. *Fibers and Polymers.* 9 (6), 735-739.
[22] Ray, A.K., Das, S.K., Mondal, S., Ramachandrarao, P., (2004). Microstructural characterization of bamboo. *Journal of Materials Science.* 39 (3), 1055-1060.
[23] Xu, X., Wang, Y., Zhang, X., Jing, G., Yu, D., Wang, S., (2006). Effects on surface properties of natural bamboo fibers treated with atmospheric pressure argon plasma. *Surface and Interface Analysis* 38 (8), 1211-f1217.
[24] Das, M., Pal, A., Chakraborty, D., (2006). Effects of mercerization of bamboo strips on mechanical properties of unidirectional bambooenovolac composites. *Journal of Applied Polymer Science* 100 (1), 238-244.
[25] Erdumlu, N., Ozipek, B.,(2008). Investigation of regenerated bamboo fibre and yarn characteristics. *Fibres and Textiles in Eastern Europe* 4 (69), 43e47.
[26] Jais, F. N. M., Mokeramin, M., Roslan, M. N., Halip, J. A., & Jusoh, W. A. W. (2023). Bamboo Fiber for Textile Applications. In Multifaceted Bamboo: Engineered Products and Other Applications. Springer Nature Singapore. pp. 275-290.
[27] Çeven, E. K., & Karakan Günaydın, G. (2021). Evaluation of some comfort and mechanical properties of knitted fabrics made of different regenerated cellulosic fibres. *Fibers and Polymers,* 22(2), 567-577.
[28] Dündar E., (2008). Çeşitli Selülozik İpliklerden Üretilen Örme Kumaşların Performanslarının Karşılaştırılması, İstanbul Teknik Üniversitesi, , Fen Bilimleri Enstitüsü, Yüksek lisans tezi, İstanbul.
[29] Kim, H. A. (2021). Water/moisture vapor permeabilities and thermal wear comfort of the Coolmax®/bamboo/tencel included PET and PP composite yarns and their woven fabrics. *The Journal of The Textile Institute,* 112(12), 1940-1953.
[30] Jasińska, I. (2009). Assessment of a fabric surface after the pilling process based on image analysis. *Fibres & Textiles in Eastern Europe*, 17(2), 73.
[31] Tang, K. P. M., Kan, C. W., & Fan, J. T. (2014). Evaluation of water absorption and transport property of fabrics. Textile Progress, 46(1), 1-132. Tang, K. P. M., Kan, C. W., & Fan, J. T. (2014). Evaluation of water absorption and transport property of fabrics. *Textile Progress*, 46(1), 1-132.
[32] Seval, U. (2021). The bursting strength properties of knitted fabrics containing recycled polyester fiber. *The Journal of The Textile Institute,* 112(12), 1998-2003.
[33]Telli, T. S., & Kodaloğlu, M., (2003). Kumaş mukavemeti değişiminin uzman sistemle incelenmesi . *Tekstil Maraton Dergisi,* 13(66), 51-53.
[34]Kodaloğlu, M., Dayık, M., & Çakmak, E., (2005). Büküm kaybının kumaş mukavemeti üzerine etkisi. *Tekstil Teknik Dergisi,* 21(248), 228-230
[35] Zhang, Z., Xie, Q., Chao, T., Cui, L., Wang, P., Yu, Y., & Wang, Q. (2023). Construction of rough surface based on zein and rosin to hydrophobically functionalize cotton fabric with antibacterial activity. *Progress in Organic Coatings,* 184, 107839.
[36] Liu, C., Zhang, S., Yan, S., Pan, M., & Huang, H. (2024). Mechanical and Antibacterial Properties of Bamboo Charcoal/ZnO-Modified Bamboo Fiber/Polylactic Acid Composites. *Forests,* 15(2), 371.