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A study on comparison of air permeability properties of bamboo / cotton and cotton towels

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As a result of the literature review, it was observed that previous studies concentrated mainly on investigating the water absorption properties of towel fabrics, but limited studies analyzed air permeability properties of towel fabrics. The purpose of this study is to investigate the air permeability of bamboo / cotton and cotton towels produced with different pile heights and to analyze the effect and importance level of pile fiber type and pile height in these two types of towel fabrics. The paper presents an investigation of the air permeability ability of towel fabrics with respect to pile height and pile fiber type. Towel fabrics were produced under industrial conditions. 100% bamboo and 100% cotton yarns were used as pile yarns, while 100% cotton yarn was used as weft and ground warp yarn. The effect of pile fiber type and pile height on the air permeability properties of fabrics was compared using analysis of variance (ANOVA). The Design Expert 6.01 program was used for statistical analyses. It was found that air permeability of bamboo/cotton towel fabrics was higher than 100% cotton towel fabrics and the air permeability of both types of towels decreased as pile height increased.

Key words: Bamboo, cotton, terry towel, air permeability, pile height.

INTRODUCTION

Clothing and textile products are the basic materials we use every day and provide physiological and psychological comfort. Towel fabric is a kind of warp pile fabric also known as Turkish towel. As one type of warp yarns forms a loop on the fabric surface, while the other type forms the ground fabric together with the weft yarn (Patil, 2015). The low-tension warp threads is woven into the fabric in such a way as to form loops on both sides of the surface. These may be "single loop terry" or "double loop terry," depending on whether one or two strands are woven together to form loop. The loop piles, increase the surface area and determine the rate and amount of water absorption. Double loop towels tend to be more absorbent than the single loop towels (EC60-1144 1960). The pile structure is one of the most important features of the towel because it has a significant effect on the structure and end-use properties of towels such as water absorption, air permeability and softness. Raw materials and pile height to be used for weft, ground warp and pile warp yarns are key parameters for design features. The properties required for yarns in towel fabrics are high absorbency, high wet strength, good washing ability and

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soft handle (Petrulyte and Baltakyte, 2008).

The comfort parameters of air permeability, water vapour permeability, liquid transfer velocity, drying time, and water absorption will stand out in towel fabrics (Ramachandran, 2015).

Air permeability is an important feature of fabrics (Sundaramoorthy et al., 2011) and is one of the main factors affecting the thermal comfort of the user (Angelova et al., 2013). ASTM D737-75 defines air permeability as air the rate of air flow passing perpendicularly through a known area under a prescribed air pressure differential between the two surfaces of a material (ASTM D737-96 1996). In summer, atmospheric heat and sweat transfer from the human body is mainly due to the permeability of the clothing material; for this reason, a highly permeable material is preferred. Winter clothing, however, should be less permeable to protect the human body from cold weather (Sundaramoorthy et al., 2011). In some products, such as tents, sleeping bags, etc., low air permeability is required to provide comfort for the wearer. Towel fabric require high air permeability for bathing gown and slippers (Petrulyte and Baltakyte, 2008, Singh and Verma, 2016). Warp and weft density are seen as the most important features affecting air permeability. The ability to limit or permit passage of airflow through the fabric depends primarily on the thickness, porosity, structure and geometry of the fabric. Air permeability increases with an increase in porosity and a decrease in the thickness of the fabric (Singh and Verma, 2016). The porosity is related to structural and geometric properties such as the type of yarns, warp and weft density, thickness etc. It determines thermal insulation efficiency and thermal comfort of garment (Angelova et al., 2013). Pile height has a significant effect on air permeability capacity of towel fabrics. Petrulyte and Baltakyte (2008) have investigated air permeability of various terry fabrics regarding the finishing process. They said that the pure linen terry fabric after such a finishing process exhibited higher air permeability then the linen/ cotton terry fabrics (Petrulyte and Baltakyte, 2008). Durur and Oner (2013) have investigated on the comfort properties of the towel fabrics and have found that an increase in pile height causes a decrease in air permeability rate and this decrease is important statistically.

Cotton and bamboo/cotton double loop towel fabrics were chosen in this study. Cotton fiber is the most used natural fiber in the towel production. Bamboo fiber is also used frequently in the production of towels in recent years. Cotton fiber towels have high absorbency and softness. Bamboo fiber began to be commonly used in textiles in recent years. Since bamboo contains bamboo extract, a substance called “Bamboo kun”, it is difficult for disease-inducing organisms or insects to affect this plant. The natural antibacterial elements in the bamboo fiber keep the bacteria away from the bamboo fabrics. Therefore, bamboo is grown naturally, without using pesticides (Wallace, 2005). Bamboo fiber is a regenerated cellulosic fiber. Bamboo fiber is softer than cotton. It has a much better moisture absorption and air permeability with various micro gaps and micro holes (Hussain et al., 2015; Das, 2018; Gökdal, 2007). Bamboo fiber garments can absorb and evaporate human sweat in a split second, as if they were breathing. Bamboo fiber makes it suitable for anti-ultraviolet natural summer clothes. Bamboo fiber products are environmentally friendly and biodegradable.

A review of the literature revealed that previous studies mainly concentrated on the investigation of water absorption properties of terry towel fabrics, while only a limited number of studies analyzed air permeability properties. The aim of this study investigate air permeability of bamboo/cotton and cotton towel fabrics produced with different pile heights; and analyzed the effect and significance level of pile fiber type and pile height on these two types of terry towel fabrics.

MATERIALS AND METHODS

Bamboo, which is used as pile yarn in bamboo/cotton towels, is extracted in the form of fiber and is converted into yarn in factories. In manufactured terry towel fabrics, 100% cotton (36.87 tex) weft yarn; 100% cotton (29.5/2 tex) warp yarn; and 100% cotton (36.87 tex) and 100% (36.87 tex) bamboo pile yarn were used. Terry towel fabrics were manufactured in a 3-weft system weaving machine at 6 different pile heights with constant densities of 17 weft/cm and 13 warp/cm. Table 1 indicates unevenness and strength properties of cotton and bamboo pile yarns used in towel fabrics. Every item listed in the table is described under the table. Table 2 indicates pile height values of towel fabrics. For pile heights, sub index references from 1 to 6 were used and the codes are presented in Table 2. These codes are also used in Figure 1.

Terry towel samples were conditioned under standard atmospheric conditions for 24 h (TS EN ISO 139 2008). Air permeability of the fabrics was measured using a Textest FX 3300 device (TS 391 EN ISO 9237 1999). Analysis of variance (ANOVA) was used to analyze interactions among independent variables and how these interactions impact the dependent variable. Relationships among variables were evaluated with one-way Anova (Field, 2005). A one-way ANOVA compares the means of two or more groups for one dependent variable (Ross and Willson, 2017). Experimental test results were used to formulate predictive equations for air permeability. One-way analysis of variance (ANOVA) was performed on the test results (at a significance level of 5%). The experimental data were analyzed by using Design Expert 6.01 statistical software.

RESULTS AND DISCUSSION

Air permeability test results for terry towel fabrics are presented in Figure 1. The results of analysis of variance are presented in Table 3. The air permeability of bamboo/cotton towels was found to be higher than that of 100% cotton towels. As pile height increased, the air permeability of towel fabrics decreased. Abd El Hady (2018) has also achieved similar results in his work. The reason for the decrease in air permeability is that the

Table 1. Unevenness, hairiness and strength properties of pile yarns.

Yarn [1]	U % [2]	-50 %, Thin places [3]	+50 %, Thick places [4]	+ 200%, Neps [5]	Hairiness (mm) [6]	Breaking strength (cN/tex) [7]	Breaking Elongation (%) [8]	TPI [9]
C	8.2	0	0	3	5.9	16.55	5.25	14.8
B	8.05	0	0	2	4.8	17.15	8.15	14.4

[1] B: Bamboo, C: Cotton
[2] U % Unevennes ; it is the percentage mass deviation of unit length
[3] Thin places; it is 50% thinner than the average mass value,
[4] Thick places; it is 50 % thicker than the average mass value,
[5] Neps; it is the 200% of the average value of the mass in the yarn section is less than 4 mm in length,
[6] Hairiness; it denotes the total amount of fibre ends projecting above the surface of the textile yarn,
[7] Breaking strength; it is the force that the yarn breaks,
[8] Breaking Elongation; it is the ratio of the amount of elongation to the initial length of the yarn until the yarn breaks,
[9] TPI; it is the twist per inch.

Table 2. Pile height values of terry towel fabrics.

Terry Towels Fabric Code(*)	Pile height (mm)
C_1,B_1	5.4
C_2,B_2	6.0
C_3,B_3	6.4
C_4,B_4	7.1
C_5,B_5	8.0
C_6,B_6	9.0

(*) B: Bamboo, C: Cotton.

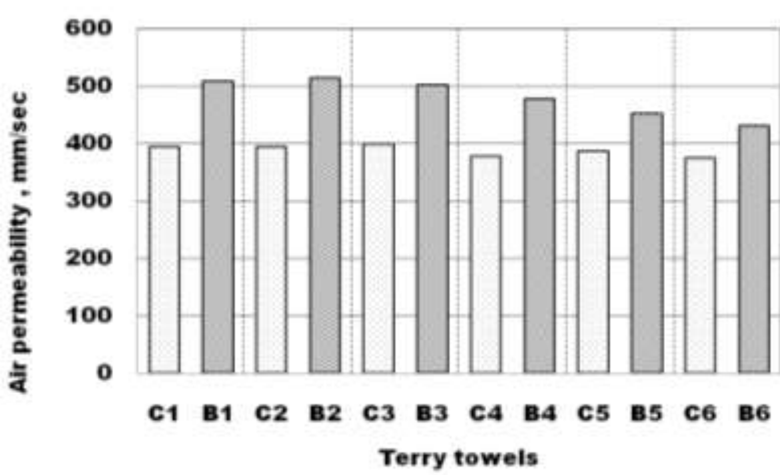

Figure 1. Air permeability of terry towel fabrics.

amount of air that can pass through the air in the high pile height is less than in the low pile height. (Abd El Hady, 2018; Durur and Öner, 2013). It was found that the interaction of pile fiber type (Y_p) and pile height (P_H) had a statistically significant effect on air permeability; coefficient of determination, R^2 value was 0.9089. R^2 is a measure of how well a model fits a data set. R^2- squared coefficient generally takes a value between 0 and 1, where 1 equates to a perfect fit of the model (Pentreath, 2015). As R^2 approaches 1, the model is stronger and explains the data correctly. This indicates that there was a good agreement between the experimental value of air

Table 3. ANOVA results for air permeability of towels.

Source	Sum of squares	DF*	Mean square	F value	P
Model	301992.5	3	100664.2	369.07	< 0.0001
Y_p	252283.8	1	252283.8	924.96	< 0.0001
P_H	19378.34	1	19378.34	71.05	< 0.0001
Y_p P_H	6672.534	1	6672.534	24.46	< 0.0001
R^2	0.9089				

*DF: degrees of freedom.

permeability and the predicted one from this model. Pile fiber type, pile height and the interaction of these two independent variables explained 91% of the variability in air permeability. Statistical analyses indicated that independent variables had a significant effect on air permeability ($p<0.0001$) (Table 3). Because the p-values are smaller than 0.05, the independent variables have significantly contributions on model. p-value is the probability that the results of the study being due to only chance. If the p value is less than 0.05, the results are said to be statistically significant, conversely results are said to be not statistically significant when the p value is greater than 0.05. (Glasziou et al., 2009).

Regression equations were created for towel fabrics with bamboo and cotton pile yarns in order to predict air permeability thereby permitting air permeability to be predicted before weaving, based on pile height. Regression Equations 1 and 2 which explain the relationship between the independent variables pile yarn and pile height and the dependent variable air permeability, are presented thus.

$$A_{Pc} : 418.1660071-4.305394811x\ P_H \quad (1)$$

$$A_{Pb} : 601.4484765-16.53367981x\ P_H \quad (2)$$

A_{Pc} : Air permeability of towel fabrics with cotton pile
A_{Pb} : Air permeability of towel fabrics with bamboo pile

Conclusions

The results indicate that:

(i) An increase in pile height negatively affects the air permeability of towels. As pile height increases, air permeability decreases. The reason of this, the air passage from the high-pile towels is less than low-pile towels.
(ii) The air permeability of towels with bamboo pile are better than those of towels with cotton pile yarns. This is because bamboo fiber has high air permeability due to the micro gaps in its profile than cotton fiber.
(iii) As a result of this study, it was possible to predict the air permeability of terry towels, before the production of the terry towels by using obtained regression equations.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests

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