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Design of a light weight fabric from natural cellulosic fibers with improved moisture related properties

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Abstract. This paper investigated moisture related comfort properties of woven fabrics from natural cellulosic fibers, namely cotton, linen, and Crailar. The comfort properties of the fabrics were measured in accordance with the relevant standards, and the results were comparatively discussed. In addition to that, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) together with Analytic Hierarchy Process (AHP) was employed to determine the most preferable fabric based on comfort properties.

1. Introduction

Three main aspects of clothing comfort are psychological, sensorial and thermo-physiological comfort. Psychological aspect of comfort is mainly related to the design of the clothing whereas sensorial comfort is related with the feeling of people when the dress touchs the skin. The thermosphysiological (thermal) comfort properties, on the other hand, such as air permeability, water vapour permeability, thermal resistance, wickability, absorbency, the drying rate and water resistance are altered by the fiber properties, yarn structure, fabric construction, and chemical finishing treatments. For providing satisfactory thermal comfort, clothing should possess good moisture related properties [1-3]. Although synthetic fabrics have convincing properties, due to their hydrophobic nature they may not provide satisfactory comfort to the wearer compared to fabrics from natural fibers. Cotton is a cellulosic based, widely-used natural fiber thanks to its good comfort properties and versatility. Flax is another cellulosic based fiber having distinctive properties such as moisture absorbency and breathing capability. Crailar is a newly emerging flax based fiber produced by using the Crailar process. In the process, finer shorter-length fibers performing cotton characteristics, are seperated from bast of flax plant (with an enzymatic treatment which does not alter the chemical structure.) As a result of the process crailar shows similar characteristics with cotton in terms of comfort aspects, handle, look, wrinkle and moisture-related properties [4-5]. There are several studies in the literature that examined the comfort related properties of natural cellulosic fiber woven fabrics. [6-9]. The study discussed in this paper was conducted in an attempt to investigate some moisture related comfort properties of woven fabrics from natural cellulosic fibers, namely cotton, linen, and Crailar.

2. Experimental Study

For the study, five different woven fabrics having 3/1 Z twill construction were produced using Cotton (Ne 14), 60/40 Cotton/Crailar (Ne 13) and Linen (Ne 12) yarns either in weft, warp or both directions.

Natural cellulosic fibers are used for designing more environmental friendly fabrics which is one of the aim of this study. Physical properties of these yarns are shown in the Table 1.

Table 1. Physical properties of Cotton (Co.), 60/40 Cotton/Crailar* (Cr.) and Linen (Li.) yarns.

	Co.	Cr.	Li.
Yarn Count (Ne) (TS 244 EN ISO 2060)	14	13	12
Yarn Tensile Strength (CN/tex, CV%) (TS EN ISO 2062)	13.65;7.54	8.19;10.86	31.8;14.92
Twist (t/m – Z; CV%)	451.6;0,07	366.2;0.27	369.6;0.07
Twist factor : α_e	3.06	2.58	2.71

*For simplicity and clear understanding, 60/40 % Cotton/Crailar yarns were shown as Crailar (Cr.) only.

Sw550 automatic warping machine and S1 8900 automatic rapier weaving machine (184 cm x, 111 cm x 140 cm) and reed width of 51 cm, was used for the work. 18 heald frames out of 20 were used during the production. Five different types of fabrics in warp and weft wise (Warp/Weft) were designed to weave as Co.-Co.; Co.-Li.; Co.-Cr.; Cr.-Cr. and Li.-Li fabrics.

Table 2. Parameters of the fabrics produced for the study

Fabric Type	Thickness (mm)	Weight (g/m^2)	Warp density (ends/cm)	Weft density (picks/cm)	Porosity (%)	Cover factor (%)
Co.-Co.	1.78	224.02	29.2	24.4	91.82	88
Co.-Li.	1.78	246.28	28.8	24.5	91.01	89
Co.-Cr.	1.93	230.37	29.6	24.6	92.24	89
Cr.-Cr.	1.81	230.21	29.2	23.8	91.74	89
Li.-Li.	1.81	249.66	28	23	91.04	89

Water Vapor Permeability, wicking, air permeability and rigidity tests were done according to BS 7209: 1990, DIN 53924, ASTM D737 and ASTM D4032 429594 – 1 standards, respectively. Transfer wicking test was made according to the method of Zhuang [10] with the difference that the applied pressure is 154 g/m^2. Drying rate was measured based on Coplan's research [11] with the difference that the sample size is 75 mm diameter. Drying rate is calculated at the end of the test [12].

2.1. A General Introduction to Topsis (Technique for Order Preference by Similarity to Ideal Solution) and AHP (Analytic Hierarchy Process)

Multi-criteria decision making (MCDM) methods deal with the process of making decisions in the presence of multiple objectives. Hwang and Yoon (1981) developed the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) based on the concept that the chosen alternative should have the shortest distance from the positive-ideal solution and the longest distance from the negative-ideal solution [13]. In TOPSIS method there are six steps which can be briefly listed as:

(1) The normalized decision matrix is calculated.
(2) The weighted normalized decision matrix is calculated.
(3) The positive ideal and negative ideal solution are determined.
(4) The separation measures using the n-dimensional Euclidean distance are calculated.
(5) The relative closeness to the ideal solution is calculated.
(6) The preference order is ranked.

TOPSIS assumes that each attribute takes either monotonically increasing or monotonically decreasing utility. That is, the larger the attribute outcome, the greater the preference for benefit attributes and less the preference for cost attributes [14]. In AHP, firstly the alternatives and the significant attributes are identified. For each attribute and each pair of alternatives, the decision makers specify their preference in the form of a fraction between 1/9 and 9. Decision makers similarly indicate the relative significance of the attributes. Then, each matrix of preferences is evaluated by using eigen values to check the consistency of the responses. Finally, a score is calculated for each alternative [15]. Table 3 shows the calculated weights for the six criteria, namely water vapour permeability, wicking, transfer wicking ratio, drying speed, air permeability and rigidity, of the woven structures. Determination of the criteria weights was worked out using Analytic Hierarchy Process (AHP).

Table 3. The Criteria Weights.

Criteria (C)	Weights
C1: Water vapour permeability	0.25
C2: Wicking	0.20
C3: Transfer wicking ratio	0.20
C4: Drying speed	0.10
C5: Air permeability	0.10
C6: Rigidity	0.15

3. Results and Discussion

The results of the experimental study are given in Figures from 1 to 5.

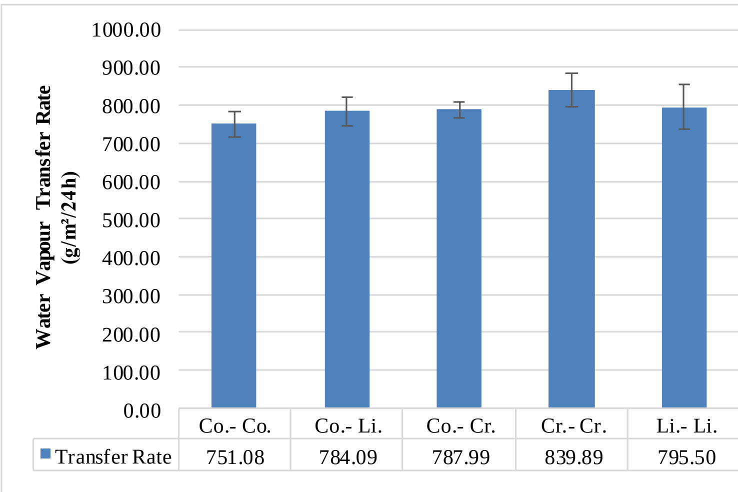


Figure 1. Water vapour permeability of fabrics.

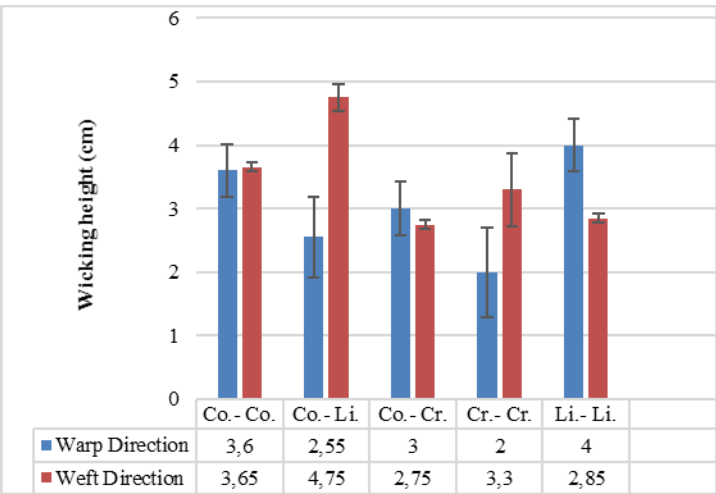
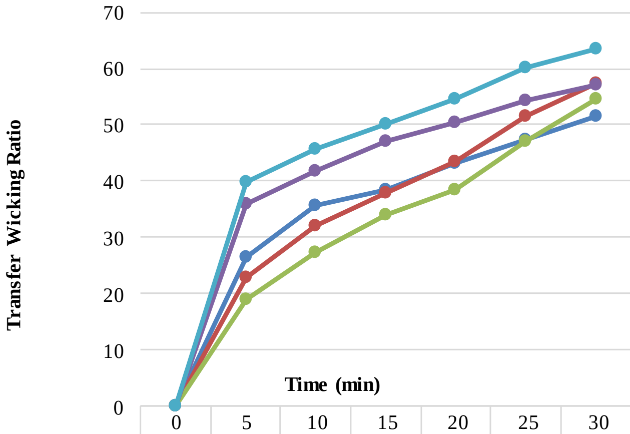


Figure 2. Wicking height in 5 minutes.

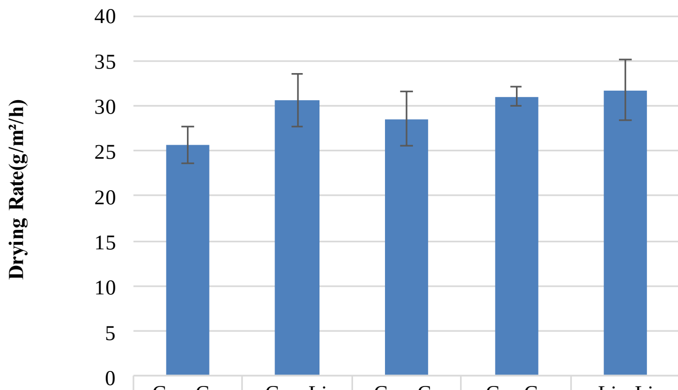
From the results presented in Figure 1, it can be stated that the highest water vapour permeability value was obtained for Cr.-Cr. fabric; this was followed by Li.-Li., Co.-Cr., Co.-Li. Besides, Co.-Co. had the lowest value.
Li.- Li. fabric had the highest wicking height in warp direction. This was followed by Co.-Co., Co.-Cr., Co.-Li and finally Cr.-Cr. fabric, in turn (Figure 2). On the other hand, Co.- Li fabric had the highest value in weft direction, this was followed by Co.-Co., Cr.-Cr., Li.-Li. and Co.-Cr. fabric, in turn. Also, it was seen from the Figure 2 that, in the weft direction, Co.-Li fabric behaved substantially differently from the other types of fabrics.



	0	5	10	15	20	25	30
Co.- Co.	0	26.499	35.557	38.389	43.025	47.322	51.584
Co.- Li.	0	22.685	31.955	37.872	43.569	51.57	57.31
Co.- Cr.	0	18.861	27.232	34.016	38.481	46.997	54.581
Cr. - Cr.	0	35.806	41.746	47.095	50.498	54.428	57.001
Li.- Li.	0	39.722	45.706	49.999	54.651	60.293	63.569

Figure 3. Transfer wicking ratio against time.

Figure 3 shows that the transfer wicking of fabrics had the same trend, where there was a steep increase during the first 5 minutes followed by a slower increase thereafter. Li.-Li fabric had the highest transfer wicking ratio and this was followed by the Cr.-Cr, Li.-Li., Co.-Li., and finally Co.-Cr. fabric, in turn. The results concerning the drying test is presented in Figure 4. According to the results Li-Li. and Cr.-Cr. fabrics had the highest drying rates in terms of g/m²/hour. These were followed by the Co.-Li., Co.-Cr, and Co.-Co. fabric, in turn.



	Co.- Co.	Co.- Li.	Co.- Cr.	Cr.- Cr.	Li.- Li.
Drying rate	25.62	30.64	28.59	31.07	31.78

Figure 4. Drying rates of fabrics.

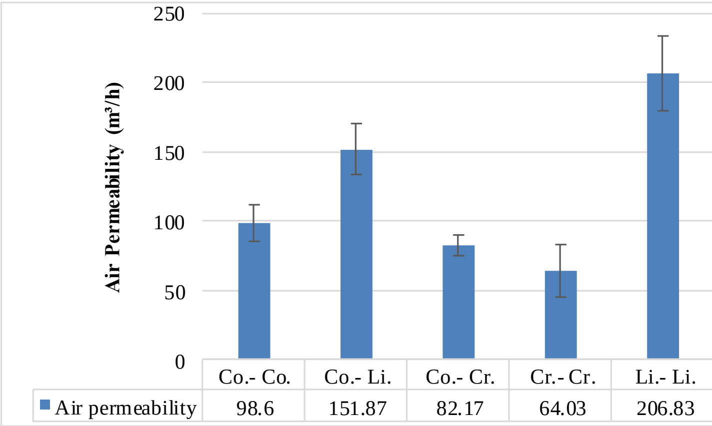


Figure 5. Air permeability of fabrics

The results presented in Figure 5 showed that the air permeability of the Li.-Li. fabric was the highest, followed by the Co.-Li., Co.-Co., Co.-Cr. and Cr.-Cr. fabrics, in turn. The statistical analysis of the data revealed that Li.-Li. fabric behaved significantly differently from other types of fabrics in terms of air permeability.

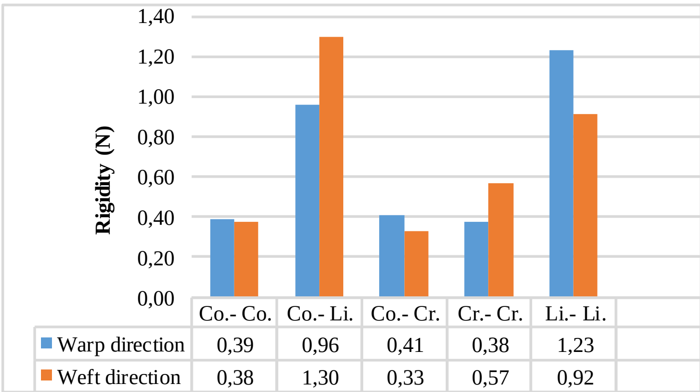


Figure 6. Rigidity of fabrics.

The results presented in Figure 6 showed that the rigidity of Li.-Li. fabric was the highest in warp direction; followed by Co.-Li., Co.-Cr., Co.-Co., and Cr.-Cr. fabric, in turn. On the other hand, in weft direction, Co.-Li. had the highest value; this was followed by the Li.-Li., Cr.-Cr., Co.-Co., and finally Co.-Cr., in turn.

3.1. Application of TOPSIS Method

Vector normalization was prepared and weighted normalized matrix was constituted. Accordingly, positive and negative ideal solutions were determined. Distances from the ideal solutions, both positive and negative, were calculated. Ideal Solution based on the concept that the chosen alternative should have the shortest distance from the positive-ideal solution and the longest distance from the negative-ideal solution. In Table 4 preference order was ranked.

Table 4. Preference Order

Alternatives	S*	S^-	$C^* = S_i^- / (S_i^* + S_i^-)$	
	Value	Value	Value	Rank
Co.-Co.	0.0459	0.0721	0.6112	1
Co.-Li.	0.0727	0.0426	0.3696	5
Co.-Cr.	0.0574	0.0674	0.5400	2
Cr.-Cr.	0.0571	0.0636	0.5270	3
Li.-Li.	0.0623	0.0627	0.5016	4

Based on final ranking of TOPSIS method, Co.-Co. fabric seems to have the most preferable fabric based on comfort properties, and this was followed by Co.-Cr., Cr.-Cr., Li.-Li., and Co.-Li. fabric, in turn. The results of the experimental study together with TOPSIS evaluation revealed that employing Crailar yarns in the fabric structure together with cotton had a positive effect on comfort related properties.

4. Conclusion

The results of the study showed that a fabric construction having Crailar yarn in the weft and cotton yarn in the warp can be a good choice for designing summer denim clothes. High physical properties and producibility are provided by cotton yarn as warp, and high comfort properties are achieved by both crailar and cotton yarn. In other words, Cotton yarn causes improvement of tactile comfort properties and Crailar yarn enhances the thermal comfort properties of the fabric. Both of them together, increase the psychlogical comfort properties of the fabric. Moreover, if the crailar percentage of cotton/crailar yarn is increased, higher comfort properties is achived in comparison to those properties of the 60/40 cotton/crailar yarn. When the all criteria are evaluated, Co.-Cr. fabric type is the best alternative for producing lightweight, comfort related properties improved, producible and productive fabric.

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