(REFEREED RESEARCH)

INVESTIGATION OF AIR PERMEABILITY AND MOISTURE MANAGEMENT PROPERTIES OF THE COMMERCIAL SINGLE JERSEY AND RIB KNITTED FABRICS

TİCARİ SÜPREM VE RİBANA ÖRME KUMAŞLARIN HAVA GEÇİRGENLİĞİ VE NEM YÖNETİMİ ÖZELLİKLERİNİN ARAŞTIRILMASI

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ABSTRACT

The aim of the study was to determine the effects of knitting type, yarn count and mass of commercially knitted fabrics on comfort parameters including air permeability and moisture management. For this purpose, comfort properties of 100% cotton single jersey, 1x1 and 2x1 rib fabrics were determined. Air permeability and moisture management properties were measured by using TexTest FX3300-III air permeability tester instrument and SDL Atlas MMT Moisture Management Tester, respectively. The results indicated that commercial knitted fabrics' air permeability decreased unproportional to the mass of fabrics. Rib fabrics had higher air permeability values compared to single jersey fabrics. Furthermore, 30/1 single jersey and rib fabrics' moisture management properties decreased as the fabrics' mass increased. The results also indicated that wetting time and absorption rate increases as the single jersey fabrics' mass increases.

Keywords: Air permeability, clothing comfort, commercially knitted fabric, fabric mass, moisture management, yarn count.

ÖZET

Bu çalışmanın amacı, örgü yapısı, iplik numarası ve gramajın ticari örme kumaşların konfor özelliklerine etkisinin araştırılmasıdır. Bu amaçla % 100 pamuk süprem, 1x1 ribana ve 2x1 ribana kumaşlar araştırılmıştır. Hava geçirgenliği ve nem yönetimi özellikleri sırasıyla TexTest FX3300-III hava geçirgenliği ölçüm cihazı ve SDL Atlas MMT nem yönetimi ölçüm cihazı kullanılarak yapılmıştır. Çalışma sonuçlarına göre ticari kumaşların hava geçirgenliği değerleri gramaj arttıkça düşecek şekildedir. Örgüler karşılaştırıldığında rib örgülü kumaşların hava geçirgenliğinin süprem örgülü kumaşların hava geçirgenliğine göre daha yüksek olduğu görülmektedir Bunun yanı sıra, 30/1 süprem ve rib örgülü kumaşların nem iletim özellikleri artan gramaj ile düşecek şekildedir. Çalışma sonuçları aynı zamanda süprem kumaşların gramaj değeri arttıkça, ıslanma zamanı ve absorbsiyon oranının da arttığını göstermektedir.

Anahtar Kelimeler: Hava geçirgenliği, giysi konforu, ticari örme kumaş, kumaş gramajı, nem yönetimi, iplik numarası.

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1. INTRODUCTION

Comfort properties of fabrics are mainly affected by fabrics' raw material and mass, heat and moisture transfer characteristics, and tactile sensations. Environmental factors such as air temperature, velocity, and relative humidity, radiant temperature also alter fabrics' comfort. Clothing comfort is classified into three categories: psychological, physiological (sensorial) and thermophysiological (thermal) comfort. The thermophysiological comfort, which includes the subject of this research, depends on thermal, moisture and air permeability properties (1).

Air permeability is defined as "vertical air flow rate through a test subject" by Turkish Standards Institute (2). It is especially critical for the performance of functional textile products such as industrial filters, tents, sails, parachutes, airbags, raincoat fabrics and outdoor clothing (3). Fabrics with low air permeability are preferred for outdoor clothing in order to enable protection against the wind (4). Air permeability is also directly associated with other comfort parameters such as thermal resistance and moisture permeation. An air permeable fabric also allows the transition of liquid and vapor. Furthermore, thermal resistance is related with the air trapped between the skin and the clothing. Knitted fabrics are preferred for human clothing as they are more air permeable than woven fabrics (5-6). Therefore, determination of air permeability of knitted fabrics is important for the textile industry.

Moisture management property of fabrics has a great impact on thermo-physiological balance and comfort of the body (7-8). A fabric with good moisture management allows transmission of perspiration (9). Fabric mass and structure, fiber type, yarn count and yarn twist coefficient, as well as finishing processes, determine the fabric's moisture management capacity (10-13). Liquid permeability of fabrics is defined by two parameters, wetting and wicking (14-15). Wetting is defined as the displacement of fiber-air interface with the fiber-liquid interface. Wicking is spontaneous liquid flow through porous fabrics via capillary forces. Wetting leads to capillary forces that consequently results in wicking (16). Water repellent fabrics are produced by coating of fabric with hydrophobic layers during finishing processes. They are especially used in the production of outdoor clothing, furniture, and mattress pads. On the other hand, liquid absorbing materials are preferred for diapers.

Fabrics knitted with basic weft-knitted structures such as single-jersey and rib are produced for large scale of products such as infant/baby clothing, underwear and technical outdoor products (17). Mavruz et al., have previously determined air permeability of single jersey and rib knitted fabrics with different yarn counts. They showed that single jersey fabrics have better air permeability values than rib fabrics (18). In addition, moisture management properties of knitted fabrics have been previously studied by Ozdil et al. For single jersey fabrics moisture management properties including maximum absorption rate, spreading speed and maximum wetted radius have been shown to increase proportional to yarn count (19). According to OMMC values, all single jersey fabrics with yarn count Ne 20, 30, 40 have been found in the same category 'good'. We proposed that thermophysiological comfort parameters of commercially available knitted fabrics alter depending on the fabric structure and yarn count. For this purpose, air permeability and moisture management properties of commercially knitted fabrics with different structures and yarn counts were determined.

2. MATERIALS AND METHODS

2.1. Fabrics' properties

Single jersey and rib fabrics are used for outerwear, activewear, underwear and etc. Fabrics used in this study were selected due to common commercial use in textile industry. All fabrics were knitted with using 100% combed cotton (Co) ring yarn in Deniz Textile Company (Denizli, Turkey). The knitting process of the single jersey fabrics was performed on a 28 gauge and 30'' diameter Keumyong circular knitting machine. Other samples were produced on an 18 gauge and 34'' diameter Keumyong circular knitting machine. Before measurements, all the fabrics were washed in accordance with manufacturer's guidelines (detergent and temperature) to remove silicone-based softener. Methods and standards which were used to determine fabrics' properties are given in ***Table 1***.

Course and wale density were determined by counting the number of courses and wales per centimeter according to TS EN 14971. Wales per cm; the number of visible loops per unit length (cm) measured along a course. Courses per cm; the number of visible loops per unit length (cm) measured along a wale Loop length was determined in accordance with the standard TS EN 14970. Tightness factor of the fabrics was determined using the ***Equation 1*** where *T* is the yarn count in tex and *l* is loop length in mm. The fabrics' properties and air permeability values were given in ***Table 2***.

Equation 1 *Tightness Factor* = $\sqrt{T} / l$

Table 1. Methods and Standards

Methods	Standards
Wale count	TS EN 14971
Course count	TS EN 14971
Loop Length	TS EN 14970
Air Permeability	EN ISO 9237
Moisture Management	AATCC 195-2009

Table 2. Fabrics' properties and air permeability values.

Structure	Yarn count (Ne)	Mass (g/m^2)	Course count per cm	Wale count per cm	Loop Length (mm)	Tightness Factor TF	Air Permeability (mm/s)
Single jersey	24/1 (24.6 tex)	144	18.3	15.3	0.2646	18.74	741
		155	18	14.3	0.2756	17.99	709
		175	19.7	14.3	0.2792	17.76	406
	30/1 (19.7 tex)	129	16.7	14.7	0.2800	15.85	802
		140	18.3	15.3	0.2534	17.51	556
		152	19.3	15	0.2632	16.86	433
		163	17.3	14	0.2790	15.90	305
1x1 Rib	30/1 (19.7 tex)	174	16	21.7	0.2744	16.17	986
		184	17.3	20	0.2842	15.61	710
		195	17	21.3	0.3046	14.57	633
2x1 Rib	30/1 (19.7 tex)	170	17	15	0.3946	11.24	1125
		183	17	15.8	0.3890	11.40	980
		196	17	16.3	0.3694	12.01	860
		216	17.7	18.3	0.3274	13.55	550

2.2. Air permeability

Air permeability of the fabrics was measured based on EN ISO 9237 standard by using FX3300-III (TEXTEST AG) at 20 ± 2 °C and 65 ±2 % humidity. The instrument was calibrated before the experiments using calibration check plate. Pre-conditioning of all fabrics were carried out in a conditioning room at 65 ±2 % relative humidity and 20 ± 2 °C for 24 hours. Measurements were performed by application under 100 Pa air pressure per 20 cm^2 fabric surface. Averages of measurements from 10 different areas of fabrics were calculated. Results were expressed as “mm/sec”.

2.3. Moisture management

Moisture management of fabrics measured based on AATCC 195-2009 standards by using Moisture Management Tester (MMT, SDL Atlas) instrument that consists of upper and lower concentric moisture sensors. All fabrics were washed in accordance with the standards and cut diagonally into 5 different specimens (8x8 cm) across the width of a sample. Samples were conditioned at 65±2 % relative humidity and 21±1°C for 24 hours in accordance with ASTM D 1776 standards. Standard test solution (%0.9 sodium chloride that mimics human sweat) was applied onto the fabric surface that will be in contact with skin. Results were expressed as wetting time (sec), absorption rate (%/sec), spreading speed (mm/min), maximum wetted radius (mm) for the top and bottom surfaces. In addition, overall (liquid) moisture management capability (OMMC) of the fabrics was calculated. *Wetting time* is the time in seconds when the top and bottom surfaces of the specimen begin to be wetted after the test is started. A*bsorption rate* is the average speed of liquid moisture absorption for the top and bottom surfaces of the specimen during the initial change of water content during a test. *Spreading speed* is the accumulated rate of the surface wetting from the centre of the specimen where the test solution is dropped to the maximum wetted radius. *Maximum wetted radius* is the greatest ring radius measured on the top and bottom surfaces. *Overall (liquid) moisture management capability (OMMC)* is an index of the overall capability of a fabric to transport liquid moisture as calculated by combining three measured attributes of performance: the liquid moisture absorption rate on the bottom surface, the one-way liquid transport capability, and the maximum liquid moisture spreading speed on the bottom surface.

2.4. Statistical Analysis

Graphics were produced by using GraphPad Prism5. The results were given as mean ± standard error of the mean. “n” represents the number of samples used. Statistical significance was evaluated using Student’s *t*-test. $p < 0.05$ was considered significant. Statistical analysis can be seen on the Figures. Statistical significance between two groups was evaluated using parametric student t-test. This test is chosen based on the assumption that population has normal distribution when each data is independent, not paired.

3. RESULTS AND DISCUSSION

In our study, we determined two comfort parameters, air permeability and moisture management of commercially knitted fabrics that commonly used for outerwear, activewear and underwear. Air permeability and moisture management of single jersey and rib knitted fabrics’ with different yarn counts and masses were studied.

3.1. Air permeability

Air permeability affects the wind resistance, water vapor permeability, and filtering properties of clothing. The air permeability properties of knitted single jersey fabrics used in our study were given in ***Figure 1***. Air permeability of single jersey fabrics significantly increased proportionally to the yarn count ($p < 0.01$, n=10) in accordance with previous reports (18;20). Single jersey fabrics have a more porous structure as the yarn count increases. In addition, the air permeability of single jersey fabrics knitted with a particular yarn count significantly decreased as the mass increased ($p < 0.01$, n=10).

Air permeability results of rib (1x1 and 2x1) fabrics used in our study were given in ***Figure 2***. Air permeability of both 1x1 and 2x1 rib fabrics knitted with different yarn counts were significantly ($p < 0.01$, n=10) decreased proportionally to the mass. 2x1 rib fabric knitted with Ne 30/1 and had a mass of 170 g/m^2 was the most air-permeable sample among all fabrics.

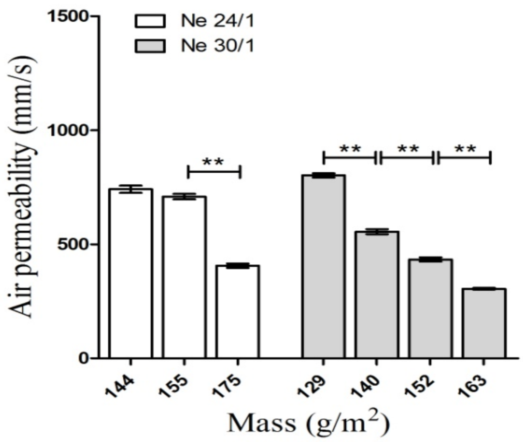

Figure 1. Air permeability of single jersey fabrics (**p < 0.01, n=10).

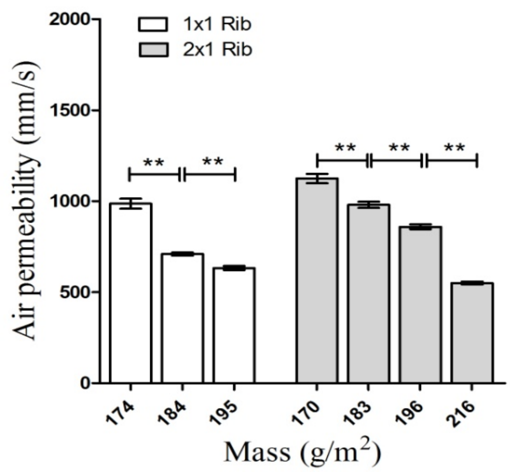

Figure 2. Air permeability of rib fabrics (**p < 0.01, n=10).

3.2. Moisture management

Fabrics' moisture management properties influence the human perception of moisture sensations significantly. In our study, MMT instrument was used to determine the moisture management properties of single jersey and rib fabrics. Previously, the moisture management properties determined using MMT instrument were compared with subjective moisture sensations (21). It was concluded that subjective moisture perceptions such as clammy and damp correlate with MMT measurements.

The wetting time values of the top and the bottom surfaces of the fabrics were given in ***Figure 3***. The wetting time of all fabrics' bottom surfaces was similar to those for top surfaces. For single jersey fabrics, 24/1 144 and 175 gr/m^2 , $p<0.01$, n=3-5), 30/1 129 and 163 gr/m^2 $p < 0.05$, n=4-5) the wetting time significantly increased proportional to the mass, as expected. Fabrics become denser as the mass increases and leads to increment of wetting time. For rib fabrics, wetting time was similar for all structures and masses, possibly due to the low mass interval.

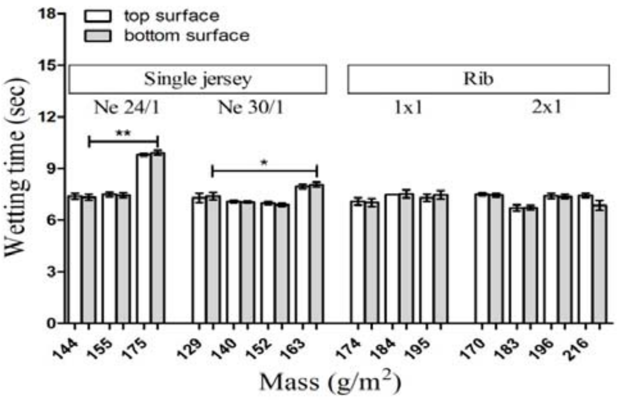

Figure 3. Wetting time of single jersey and rib fabrics (*$p < 0.05$, n=4-5, **$p < 0.01$, n=3-5).

As shown in ***Figure 4***, the absorption rate of bottom surfaces was significantly ($p<0.01$, $p < 0.05$, n=3-5) higher than top surfaces for the single jersey, except 24/1 144 and 175 gr/m^2 and rib fabrics except 30/1 174 gr/ m^2 inconsistent with a previous report (19). The absorption rate did not change according to yarn count and mass for all fabrics.

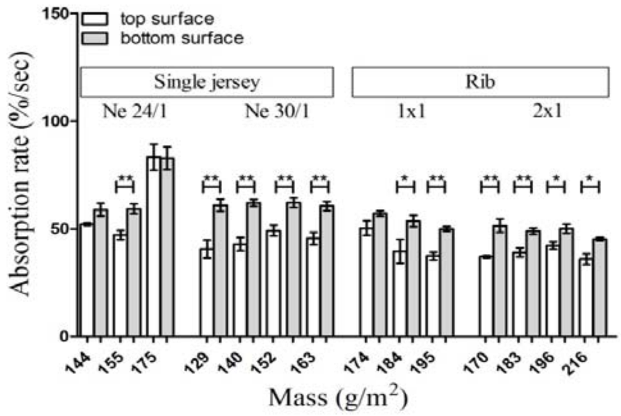

Figure 4. The absorption rate of single jersey and rib fabrics (*$p < 0.05$, **$p < 0.01$, n=3-5).

The wetting time of all fabrics' bottom surfaces was similar to those for top surfaces except 24/1 single jersey 175 gr/m^2 $p < 0.05$,n=4). The spreading speed of single fabrics increased with increasing yarn count consistent with a previous report (19). Furthermore, the spreading speed of single jersey fabrics 30/1 140 and 152 gr/m^2 significantly decreased unproportional to the mass (***Figure 5***).

The fabrics moisture management properties were also scaled on the basis of MMT manual (0-0.2: very poor, 0.2-0.4: poor, 0.4-0.6: good, 0.6-0.8: very good, >0.8: excellent). According to the OMMC values, all the fabrics used in our study had 'good' moisture management capability (***Table 3***).

Table 3. OMMC values of the fabrics.

Structure	Yarn count (Ne)	Mass (g/m^2)	OMMC value	Moisture management category
Single jersey	24/1 (24,6 tex)	144	0.4183	Good
		155	0.4587	Good
		175	0.5436	Good
	30/1 (19.7 tex)	129	0.4814	Good
		140	0.4933	Good
		152	0.4886	Good
		163	0.4496	Good
1x1 Rib	30/1 (19.7 tex)	174	0.5584	Good
		184	0.4815	Good
		195	0.4244	Good
2x1 Rib	30/1 (19.7 tex)	170	0.4422	Good
		183	0.4327	Good
		196	0.4056	Good
		216	0.3950	Good

4. CONCLUSION

In conclusion, our results showed that all commercial knitted fabrics' air permeability decreased unproportional to the mass in accordance with previous reports (18;20). Single jersey fabrics' air permeability at similar mass with different yarn count decreased with increasing yarn count as excepted. Rib fabrics showed higher air permeability when compared to single jersey fabrics in contrast to previous reports (18;20). We suggest that this discrepancy may result from commercial dyeing and finishing process and also from machine gauge which may effect the air permeability values. In our study, the knitting process of the single jersey fabrics was performed on a 28 machine gauge and rib fabrics on 18 machine gauge in accordance with commercial knitting fabric production. If single jersey fabrics' knitting process is performed using same machine gauge for rib fabrics, single jersey fabric would have high porosity thus high air permability values.

Based on our moisture management results, it can be concluded that 30/1 single jersey and rib fabrics' moisture management properties decreased as the fabrics' mass increased in accordance with a previous report (19). On the other hand, 24/1 single jersey fabrics' moisture management properties increased as the fabrics' mass increased probably due to their yarn properties. Further analysis of moisture management properties of single jersey fabrics with different yarn counts is needed to support our results. All fabrics used in our study were classified as "good" for moisture management based on OMMC values. Comparison of air permeability and moisture management of raw and commercial (dyed and finished) single jersey and rib fabrics awaits further investigation.

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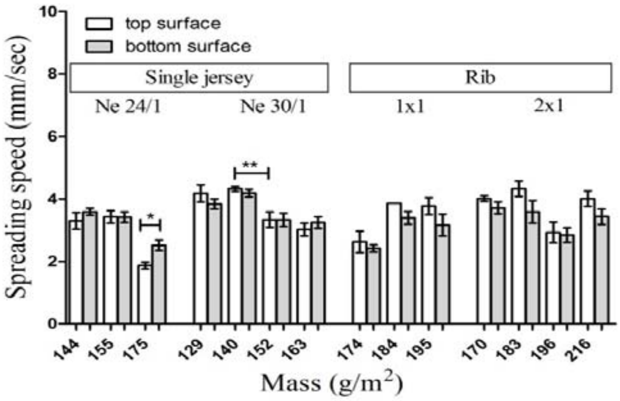

Figure 5. Spreading speed of single jersey and rib fabrics (*p < 0.05, **p < 0.01 n=4).

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