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An Experimental Study on Selected Performance Properties of 100% Cotton Terry Fabrics

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ABSTRACT

This paper presents an experimental study of the selected performance properties of 100% cotton terry fabrics. In this study, nine different constructions of terry fabrics were woven with Ne 12/1, Ne 16/1 and Ne 20/1 100% carded cotton ring spun weft yarns in three different weft densities. Fabric samples were subjected to 5 washing cycles before accomplishing the tests; air permeability, resistance to pile loop extraction, bursting strength, tensile strength, tear strength, abrasion resistance, static water absorption and drying rate. Experimental results were analyzed using General Linear Model Analysis, Correlation Analysis and Paired-Samples T Test Analysis. According to results, weft yarn count is effective on air permeability, resistance to pile loop extraction, bursting strength, tensile strength, tear strength, mass loss ratio and static water absorption whereas weft density is effective on air permeability, resistance to pile loop extraction (15, 20 and 25 mm pulling distances), bursting strength, tensile strength, tear strength, mass loss ratio and remaining water ratio. The statistical evaluations demonstrate that repeated launderings also affect the performance properties of woven terry fabrics.

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1. INTRODUCTION

Terry fabrics, which is an important part among home textiles products, have structures in the form of loops called pile on one or both sides. These products can easily absorb water and are generally used for drying purposes [1, 2]. Although the initial decision of consumers is commonly driven by touching and evaluation of appearance, terry fabrics should have such properties like hydrophility and strength, which define the performance of towels and determine their quality. As a result of the literature review, it has been determined that water absorbency property is generally evaluated in the studies that carried out on terry fabrics. Weaving process and parameters that affect the softness of woven towels have also been studied.

Considering the end use purpose, the performance of terry fabrics is mainly assessed by absorbancy. Wetting and wicking characteristics of terry fabrics have been evaluated in relation with fabric constructions, yarn materials, yarn properties and treatment processes by several test methods [3-17]. However terry fabrics are designed high weighted to absorb more water without considering longer washing and drying time requirements which cause more energy consumption. So it is important to study drying properties of terry fabrics [18]. Also studying the phenomenon of strength is an important technical step toward engineering new qualities of terry fabrics. Strength of fabric is the ability of fabric to retain its characteristic properties against various effects during end use or other places, so determines the performance characteristics of the fabrics [19]. For this purpose, performance tests (abrasion resistance, pilling, tensile strength, tear strength etc.) are applied to the woven fabrics mostly keeping relation with fibre, yarn and fabric parameters [20-24]. In addition to this one of the main problems of terry fabrics is the poor resistance of pile yarns against pull-out which affects not

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only the functionality but also the appearance of the product though this may originate from fibre, yarn and fabric parameters [25-27]. Therefore, besides the resistance to pile loop extraction, tensile, tear and bursting strength were also evaluated as describing parameters of fabric strength. Similarly, air permeability is a physical property which mostly depends on structural parameters of fabric. It is one of the extremely important properties of terry woven fabric since it influences the thermal comfort of wearer in clothing. Absorption and desorption properties of woven fabrics also depend on their air permeability [28-32].

The effects of weft yarn count, weft density and repeated laundering on softness and the predictability of terry fabrics for both purchasing and servicing have been evaluated in the previous study [33]. Within the scope of present study air permeability, resistance to pile loop extraction, bursting strength, tensile strength, tear strength, abrasion resistance, static water absorption and drying properties which are important due to the end use of terry fabrics were evaluated as selected performance characteristics. Although these performance characteristics have been described frequently in the literature, no work has yet been carried out to determine the performance of these parameters against hometype laundering and establish meaningful correlation among all of them. Therefore terry fabrics were subjected to 5 washing cycles before undergoing the performance tests considering that laundering alters the appearance and may cause dimensional change which may alter the performance properties of terry fabrics. In this study, the effects of weft yarn count, weft density and repeated laundering effects on selected performance properties of 100% cotton terry fabrics were investigated and the correlation between them was determined.

2. MATERIAL AND METHOD

The terry fabrics were woven in 9 different constructions using 3 different weft densities (22 weft/cm, 20 weft/cm and 17.5 weft/cm) and 3 different weft counts (Ne 12/1, Ne 16/1 and Ne 20/1) by a gripper weaving machine. The pile warp yarn count was Ne 16/1, the ground warp yarn count was Ne 20/2. The pile and ground warp density were 14 ends/cm for all the variants. 100 % cotton yarn was used for both weft and warp yarns. Finishing processes (bleaching, dying and washing) were applied to terry fabrics at the same bath by exhaust method. The samples were subjected to 5 washing cycles in a domestic washing machine at 40°C using detergent and softener commonly found in the market and laid on a flat surface to dry for 24 hours after each washing cycle. In the same way a total of 18 types of sample fabrics were prepared (Table 1).

Table 1. Construction properties of the finished terry fabrics

Treatment	Weft count (Ne)	Ground warp count (Ne)	Pile warp count (Ne)	Weft density (weft/cm)	Terry ratio	Weight (g/m^2)
Unwashed	12/1	20/2	16/1	22.0	5.5	449
		20/2	16/1	20.0	5.9	458
		20/2	16/1	17.2	5.6	431
	16/1	20/2	16/1	21.6	6.2	445
		20/2	16/1	20.0	6.3	471
		20/2	16/1	17.6	6.1	446
	20/1	20/2	16/1	21.2	6.5	468
		20/2	16/1	20.2	6.6	448
		20/2	16/1	17.2	6.2	432
5 washing cycles	12/1	20/2	16/1	22.0	5.4	464
		20/2	16/1	20.4	5.8	443
		20/2	16/1	18.0	5.8	434
	16/1	20/2	16/1	22.0	6.2	471
		20/2	16/1	20.8	6.5	455
		20/2	16/1	18.4	6.4	459
	20/1	20/2	16/1	21.6	6.6	466
		20/2	16/1	20.4	6.7	474
		20/2	16/1	18.0	6.6	441

Performance tests were accomplished on the samples before washing and after 5 washing cycles respectively. Each sample was conditioned at standard atmosphere (20±2 ^{0}C, 65±2 % relative humidity) before the tests were performed. Air permeability test was carried out with Prowhite Permeability Tester instrument using standard test method ISO 9237. The resistance to pile loop extraction, which is the force needed to withdraw a loop from the foundation of a terry fabric, was measured using standard test method EN 15598:2008 with Prowhite Fabric Strength Tester. The results were obtained where the pulling distance (distance between jaws) was 10, 15, 20 and 25 mm. The bursting strength of samples was measured by an automatic bursting strength tester using standard test method ISO 13938-1. Tensile strength and tear strength tests were carried out in weft direction using standard test methods ISO 13934-2 and ISO 13937-1, respectively. Abrasion resistance tests of the fabric samples were conducted on the Martindale pilling and abrasion tester in accordance with standard ISO 12947-3. The abrasion resistance of the samples were determined by the mass loss, as the difference between the initial mass and mass at the end of 2000 cycles. These values were then expressed as a percentage of initial mass and given as percent mass loss ratio. Static water absorption test was done with five samples of 10x10 cm each. Before the test, the weight of samples was measured and recorded as dry weight (md). After the samples were kept for one minute in distilled water, they were hung for three minutes to remove excess water and the weight of the wet samples (mw) was measured. The static water absorption (Sw) was calculated using Equation (1) [7].

$$\mathrm{S_w}\ \% = \frac{\mathrm{m_w} - \mathrm{m_d}}{m_d}\ \mathrm{x}\ 100 \qquad (1)$$

Drying rate was evaluated with three samples of 5x5 cm each. Before the test, the weight of the sample was measured and recorded as dry weight (md). 0.2 ml of water was dropped onto the sample using a precise dropper whose tip was about 10 mm above the fabric surface and recorded its wet weight (mw) at the initial stage. The change in weight (mf) was measured after one hour experimental duration and the remaining water ratio (Rw) was calculated using Equation (2) to determine the drying rate of the fabrics. Lower the remaining water ratio faster the drying rate [34].

$$\mathrm{R_w}\ \% = \frac{\mathrm{m_f} - \mathrm{m_d}}{\mathrm{m_w} - \mathrm{m_d}}\ \mathrm{x}\ 100 \qquad (2)$$

After the investigations of these structural and performance parameters, with a view to understanding the statistical relations among the selected performance properties all the data was analyzed by IBM SPSS Statistics-Version 25 package program. To investigate the effect of weft count and the weft density on the selected performance properties general linear model analysis was applied. Correlation analysis was applied to determine the overall statistical relationship between the values of selected performance properties and Paired samples t-tests were performed to verify the effect of laundering on the performance properties of fabric samples.

3. RESULTS AND DISCUSSION

The values of air permeability, resistance to pile loop extraction, bursting strength, tensile strength, tear strength, abrasion resistance (expressed as mass loss ratio), static water absorption and drying rate (expressed as remaining water ratio) evaluations with respect to different fabric constructions and washing cycles are given in Table 2.

Table 2. Test results

Treatment	Weft density (weft/cm)	Weft count (Ne)	Air permeability (mm/s)	Resistance to pile loop extraction (gf) Pulling distance (mm) 10 mm	15 mm	20 mm	25 mm	Bursting strength (kPa)	Tensile strength (weft) (N)	Tear strength (weft) (N)	Mass loss at 2000 abrasion cycles (%)	Static water absorption (%)	Remaining water ratio (%)
Unwashed	22	12/1	163.4	299.0	399.4	454.2	526.6	521.2	420.5	3570.7	2.2	388.1	72.6
		16/1	242.8	235.8	349.8	350.6	398.6	517.2	339.9	3333.0	1.8	461.2	75.2
		20/1	293.4	108.0	252.8	263.6	299.2	452.5	243.0	2276.0	1.4	477.4	71.8
	20	12/1	222.6	215.2	350.0	414.0	478.4	552.0	381.4	3479.3	1.6	426.8	65.9
		16/1	265.8	209.0	296.6	344.8	397.0	538.8	305.2	2964.2	1.4	459.2	77.7
		20/1	354.0	97.8	212.4	217.2	234.2	506.6	213.9	2238.8	1.2	471.4	74.2
	17,5	12/1	346.0	208.0	347.0	349.2	377.6	614.2	348.2	3238.0	0.5	427.2	79.8
		16/1	401.8	95.6	242.6	263.6	265.0	557.6	256.7	2586.7	0.4	460.0	81.6
		20/1	441.8	76.6	183.8	212.8	224.2	516.2	188.0	2060.8	0.3	475.6	82.2
5 Washing Cycles	22	12/1	129.8	432.4	632.0	651.8	730.4	592.4	441.7	2991.0	1.4	391.4	54.7
		16/1	191.8	337.8	475.8	494.6	531.4	566.2	369.9	2497.7	1.1	439.4	54.5
		20/1	214.4	308.0	456.2	489.8	504.2	511.4	253.1	1594.7	1.1	464.6	56.4
	20	12/1	158.6	399.6	506.0	566.6	578.6	601.6	433.8	2954.8	1.3	419.0	52.4
		16/1	224.2	266.4	389.0	394.8	453.2	586.6	323.5	2447.6	1.0	449.2	52.9
		20/1	257.6	244.6	359.4	406.0	459.4	515.4	232.7	1703.7	0.6	473.3	57.8
	17,5	12/1	244.8	344.2	476.2	452.4	541.4	638.4	349.4	2494.5	0.8	429.9	59.4
		16/1	308.2	252.0	389.8	388.6	430.2	617.2	278.7	2386.2	0.9	455.4	61.9
		20/1	342.0	234.0	345.8	382.0	434.0	534.6	188.5	1538.2	0.7	475.1	62.0

It is shown that, the selected performance properties are influenced by the weft density and the weft yarn count of terry towels. Finer the weft yarns, higher the air permeability and static water absorption but lower the resistance to pile loop extraction, bursting strength, tensile strength, tear strength and mass loss ratio. But variation in remaining water ratio is not regular against weft yarn count. Lower the weft densities, higher the air permeability and bursting strength but lower the resistance to pile loop extraction, tensile strength, tear strength and mass loss ratio. But variation in static water absorption and remaining water ratio are not regular against weft density.

Previous studies mainly concentrated on some important parameteres such as porosity, thickness, structure and geometry of the fabric to determine air permeability of the woven fabric. Air permeability increases with an increase in porosity that is mainly influenced by the type of fabric structure, the design of a woven, the warp and the weft densities, the size of the yarns and the type of yarn structure [35-38]. As seen in Table 2, finer the weft yarn, higher the air permeability. Also compared with more dense structure of terry fabric, the loose structure demonstrates an increase in the air permeability. The reason for the increase in air permeability is that the amount of air that can pass through the fabric woven with finer weft yarns or woven with lower weft densities increases. An increase in the weft density or weft yarn thickness should lead to a decrease in the porosity that decreases the air permeability.

The resistance of pile yarns against pull-out was also examined against the weft yarn count and weft density. As shown in Table 2, it was found that, coarser the weft yarn or higher the weft densities, higher the resistance to pile loop extraction in terry fabrics. The reason may be the increased contact length of the pile warp and weft due to the increase of the weft yarn thickness. The influence of weft density could be explained by the loops that are situated closer to each other with higher weft density and the increasing number of interlacing in the fabric. Due to a tighter structure of the fabric and the shorter intervals between intersection points, higher pulling force is required. So the resistance to pile loop extraction increases too. In addition, when analysing the 10 to 25 mm pulling distance, it was seen that the resistance to pile loop extraction increases. With the increase of pulling distance, the pile loop yarn needs to overcome higher resistance, which is originated because of more crossing points in warp/weft floats [26, 27, 39].

As expected coarser weft yarn obviously increases the bursting strength. The decrease in weft density also resulted in an increase in bursting strength. The reason of the increase in bursting strength may be the longer piles of loose fabrics that resist bursting and improve the bursting strength [40, 41].

Tensile strength of a woven fabric makes it superior in many applications as compared to non-woven and knitted fabrics. Previous studies reveal that the tensile strength of a woven fabric mainly depends on yarn linear density and weft density along with many other factors [19, 42, 43]. As stated by Kılıç&Okur if the mean diameter increases, the yarn strength increases [44]. It is obvious that the lower strength of finer yarns caused lower strength values in fabrics woven from those yarns. The influence of weft density on tensile strength may be related to the increase of yarns which bears the load in fabric structure. Tear strength is influenced by yarn linear density and weft density similarly as tensile strength. The reason for the decrease in tear strength in weft direction may be the low strength and extensibility of finer weft yarns [45, 46].

Abrasion resistance shows the fabric ability to keep its strength and appearance during friction effect. The abrasion resistance of the samples was determined by the mass loss. Results of mass loss (%) caused by abrasion after 2000 cycles showed that the mass loss ratio was lower in terry fabrics woven with finer weft yarns. Longer pile of fabrics woven with finer weft yarns may improve the abrasion resistance. Also compared with more dense structure of terry fabric, the loose structure demonstrates a decrease in the mass loss ratio. The reason may be that the increased mobility of the pile yarn beyond lower pile density reduces the mass loss. It can be stated that, terry fabrics woven with coarser weft yarns as well as higher weft densities displayed greater wear with long term use [47-49].

Terry fabrics are mainly characterised by their high water absorption ability. Static water absorption defines the amount of water which a terry fabric can absorb. As seen in Table 2, finer the weft yarns higher the static water absorption. This may be because the finer yarns make the fabric less compact and promote static water absorption by increasing the capillary size and air space within the fabric. Variation in static water absorption depending on weft density was not found to be regular despite researchers reported that static water absorption increases with increasing weft density [7, 11, 13]. Also variation in remaining water ratio is not regular against weft yarn count or weft density.

In order to understand the statistical interrelations of structural parameters and repeated laundering on the selected performance properties of woven terry fabrics General Linear Model Analysis, Correlation Analysis and Paired-Samples T Test Analysis were performed.

3.1 Effect of Weft Yarn Count and Weft Density on Performance Properties

General linear model analysis was performed by taking the variables of air permeability, resistance to pile loop extraction (10, 15, 20 and 25 mm pulling distances), bursting strength, tensile strength, tear strength, mass loss ratio, static water absorption and remaining water ratio as dependent variable separately. Tests results of Between-Subjects Effects which were obtained from the general linear model analysis are given in Table 3. It can be concluded that general linear model is affected by weft count factor in which air permeability, resistance to pile loop extraction, bursting strength, tensile strength, tear strength, mass loss ratio and static water absorption properties were selected as dependent variable. It can also be concluded that general linear model is affected by weft density factor in which air permeability, resistance to pile loop extraction (15, 20 and 25 mm pulling distances), bursting strength, tensile strength, tear strength, mass loss ratio and remaining water ratio properties were selected as dependent variable.

Homogeneous subsets which are obtained from the general linear model analysis for three different weft density groups are given in Table 4.

Table 3. Tests of Between-Subjects for unwashed fabrics

Dependent variable		**Source**	**Type III sum of squares**	**df**	**Mean square**	**F**	**Sig.**
Air permeability		Corrected model	63603.058[a]	4	15900.764	68.847	.001
		Intercept	829070.951	1	829070.951	3589.708	.000
		Weft density	42337.742	2	21168.871	91.657	.000
		Weft count (Ne)	21265.316	2	10632.658	46.037	.002
Resistance to pile loop extraction	10 mm	Corrected model	44077.547[a]	4	11019.387	8.490	,031
		Intercept	265225.000	1	265225.000	204.338	,000
		Weftdensity	11517.627	2	5758.813	4.437	,097
		Weftcount	32559.920	2	16279.960	12.543	,019
	15 mm	Corrected model	42312.871[a]	4	10578.218	42.795	,002
		Intercept	771118.151	1	771118.151	3119.606	,000
		Weftdensity	8892.702	2	4446.351	17.988	,010
		Weftcount	33420.169	2	16710.084	67.602	,001
	20 mm	Corrected model	55742.658[a]	4	13935.664	29.070	,003
		Intercept	915211.111	1	915211.111	1909.165	,000
		Weftdensity	10012.196	2	5006.098	10.443	,026
		Weftcount	45730.462	2	22865.231	47.698	,002
	25 mm	Corrected model	87347.404[a]	4	21836.851	19.790	,007
		Intercept	1138346.738	1	1138346.738	1031.668	,000
		Weftdensity	22223.182	2	11111.591	10.070	,027
		Weftcount	65124.222	2	32562.111	29.511	,004
Bursting strength		Corrected model	14217.640[a]	4	3554.410	12.087	.017
		Intercept	2534782.410	1	2534782.410	8619.363	.000
		Weft density	6488.780	2	3244.390	11.032	.024
		Weft count (Ne)	7728.860	2	3864.430	13.141	.017
Tensile strength		Corrected model	49928.218[a]	4	12482.054	207.823	.000
		Intercept	808081.138	1	808081.138	13454.315	.000
		Weft density	7386.269	2	3693.134	61.490	.001
		Weft count (Ne)	42541.949	2	21270.974	354.156	.000
Tear strength		Corrected model	2626545.567[a]	4	656636.392	32.871	.003
		Intercept	73659306.250	1	73659306.250	3687.354	.000
		Weft density	284138.960	2	142069.480	7.112	.048
		Weft count (Ne)	2342406.607	2	1171203.303	58.630	.001
Mass loss ratio		Corrected model	3.447[a]	4	.862	36.929	.002
		Intercept	12.960	1	12.960	555.429	.000
		Weft density	3.120	2	1.560	66.857	.001
		Weft count (Ne)	.327	2	.163	7.000	.049
Static water absorption		Corrected model	6285.671[a]	4	1571.418	8.089	.034
		Intercept	1819711.068	1	1819711.068	9366.543	.000
		Weft density	252.762	2	126.381	.651	.569
		Weft count (Ne)	6032.909	2	3016.454	15.527	.013
Remaining water ratio		Corrected model	182.780[a]	4	45.695	4.755	.080
		Intercept	51529.000	1	51529.000	5362.019	.000
		Weft density	138.320	2	69.160	7.197	.047
		Weft count (Ne)	44.460	2	22.230	2.313	.215

Table 4. Homogeneous subsets for unwashed fabrics (weft density factor)

Performance property		Weft density	N	Subset for alpha 0.5 1	2	3
Air permeability		22	3	233.2000		
		20	3		280.8000	
		17.5	3			396.5333
Resistance to pile loop extraction	10 mm	17.5	3	126.7333		
		20	3	174.0000	174.0000	
		22	3		214.2667	
	15 mm	17.5	3	257.8000		
		20	3	286.3333		
		22	3		334.0000	
	20 mm	17.5	3	275.2000		
		20	3		325.3333	
		22	3		356.1333	
	25 mm	17.5	3	288.9333		
		20	3		369.8667	
		22	3		408.1333	
Bursting strength		22	3	496.9667		
		20	3	532.4667	532.4667	
		17.5	3		562.6667	
Tensile strength		17.5	3	264.3000		
		20	3		300.1667	
		22	3			334.4667
Tear strength		17.5	3	2628.5000		
		20	3	2894.1000	2894.1000	
		22	3		3059.9000	
Mass loss ratio		17.5	3	.4000		
		20	3		1.4000	
		22	3			1.8000
Static water absorption		22	3	442.2333		
		20	3	452.4667		
		17.5	3	454.2667		
Remaining water ratio		20	3	72.6000		
		22	3	73.2000		
		17.5	3		81.2000	

As seen from Table 4 the air permeability, tensile strength and mass loss ratio values can be assembled into 3 subsets, resistance to pile loop extraction, bursting strength, tear strength and remaining water ratio values can be assembled into 2 subsets by weft density factor as a result of Duncan post hoc test. Homogeneous subsets for Ne 12/1, Ne16/1 and Ne 20/1 weft yarn count groups are given in Table 5.

As seen from Table 5 the air permeability, resistance to pile loop extraction (15, 20 and 25 mm pulling distances), tensile strength and tear strength values can be assembled into 3 subsets, resistance to pile loop extraction (10 mm pulling distance), bursting strength, mass loss ratio and static water absorption values can be assembled into 2 subsets by weft yarn count factor as a result of Duncan post hoc test.

3.2. Correlations Between Weft Density, Weft Count and Performance Properties

Correlation analysis was carried out to determine the overall statistical relationship among the values of selected performance properties and the results are given in Table 6.

Table 5. Homogeneous subsets for unwashed fabrics (weft yarn count factor)

Performance property		Weft count (Ne)	N	Subset for alpha 0.5 1	2	3
Air permeability		12	3	244.0000		
		16	3		303.4667	
		20	3			363,0667
Resistance to pile loop extraction	10 mm	20	3	94.1333		
		16	3		180,1333	
		12	3		240,7333	
	15 mm	20	3	216.3333		
		16	3		296,3333	
		12	3			365,4667
	20 mm	20	3	231.2000		
		16	3		319,6667	
		12	3			405,8000
	25 mm	20	3	252.5333		
		16	3		353,5333	
		12	3			460,8667
Bursting strength		20	3	491.7667		
		16	3		537.8667	
		12	3		562.4667	
Tensile strength		20	3	214.9667		
		16	3		300.6000	
		12	3			383,3667
Tear v		20	3	2191.8667		
		16	3		2961.3000	
		12	3			3429,3333
Mass loss ratio		20	3	.9667		
		16	3	1.2000	1.2000	
		12	3		1.4333	
Static water absorption		12	3	414.0333		
		16	3		460.1333	
		20	3		474.8000	
Remaining water ratio		12	3	72.7667		
		20	3	76.0667		
		16	3	78.1667		

According to correlation analysis, weft density has a positive correlation between mass loss ratio which may be due to increase in pile density and has a negative correlation between air permeability which may be explained by the interlacing density of warp and weft and closeness of loop cover that would lead to a small passageway between weft and warp yarns allowing poor air flow [30, 32]. It is also seen that weft count has a positive correlation between static water absorption conversely has a negative correlation between resistance to pile loop extraction, bursting strength, tensile strength and tear strength. Besides the correlations between the weft density, the weft count and the performance properties, selected performance properties are correlated to each other. The air permeability has a negative correlation between resistance to pile loop extraction, tensile strength, tear strength and mass loss ratio but has a positive correlation between remaining water ratio. An increase in one of the resistance to pile loop extraction, tensile strength or tear strength improves the other ones but impairs static water absorption.

3.3. Effect of Laundering on Performance Properties

The correlations between the performance properties of unwashed and laundered fabrics are given in Table 7. According to the paired samples correlations, it is confirmed the existence of correlation between performance properties of terry fabrics before laundering and after laundering.

Paired samples t-test results, which were made to verify the effect of laundering on the performance properties of fabric samples, are given in Table 8.

Table 6. Correlations

			Air permeability	Resistance to pile loop extraction Pulling distance (mm) 10 mm	15 mm	20 mm	25 mm	Bursting strength	Tensile strength	Tear strength	Mass loss ratio	Static water absorption	Remaining water ratio
Weft density		Pearson Correlation	-.787*	.483	.448	.413	.482	-.649	.384	.321	.911**	-.175	-.659
		Sig. (2-tailed)	.012	.188	.226	.270	.189	.059	.308	.399	.001	.652	.054
Weft count		Pearson Correlation	.574	-.809**	-.878**	-.891**	-.842**	-.698*	-.921**	-.921**	-.304	.886**	.272
		Sig. (2-tailed)	.106	.008	.002	.001	.004	.037	.000	.000	.427	.001	.479
Air permeability		Pearson Correlation		-.866**	-.842**	-.868**	-.907**	.123	-.836**	-.788*	-.944**	.650	.741*
		Sig. (2-tailed)		.003	.004	.002	.001	.752	.005	.012	.000	.058	.022
Resistance to pile loop extraction	10 mm	Pearson Correlation			.963**	.953**	.954**	.301	.952**	.945**	.716*	-.814**	-,405
		Sig. (2-tailed)			.000	.000	.000	.432	.000	.000	.030	.008	,279
	15 mm	Pearson Correlation				.963**	.951**	.360	.987**	.973**	.656	-.835**	-,458
		Sig. (2-tailed)				.000	.000	.342	.000	.000	.055	.005	,215
	20 mm	Pearson Correlation					.994**	.332	.987**	.961**	.675*	-.874**	-,515
		Sig. (2-tailed)					.000	.383	.000	.000	.046	.002	,156
	25 mm	Pearson Correlation						.250	.971**	.940**	.734*	-.844**	-,570
		Sig. (2-tailed)						.517	.000	.000	.024	.004	,109
Bursting strength		Pearson Correlation							.400	.477	-.386	-.446	.321
		Sig. (2-tailed)							.286	.194	.305	.229	.400
Tensile strength		Pearson Correlation								.982**	.637	-.885**	-.485
		Sig. (2-tailed)								.000	.065	.002	.186
Tear strength		Pearson Correlation									.588	-.819**	-.423
		Sig. (2-tailed)									.096	.007	.257
Mass loss ratio		Pearson Correlation										-.457	-.755*
		Sig. (2-tailed)										.216	.019
Static water absorption		Pearson Correlation											.340
		Sig. (2-tailed)											.371

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 7. Paired samples correlations

Paired performance properties		N	Correlation	Sig.
Air permeability		9	.983	.000
Resistance to pile loop extraction	10 mm	9	.842	,004
	15 mm	9	.887	,001
	20 mm	9	.821	,007
	25 mm	9	.849	,004
Bursting strength		9	.888	.001
Tensile strength		9	.988	.000
Tear strength		9	.951	.000
Mass loss ratio		9	.768	.016
Static water absorption		9	.960	.000
Remaining water ratio		9	.771	.015

Table 8. Paired samples t-test for performance properties before and after laundering

Paired performance properties		Paired differences							
					95% confidence interval of the difference				
		Mean	Std. deviation	Std. error mean	Lower	Upper	t	df	Sig.
Air permeability		73.35556	26.51316	8.83772	52.97573	93.73538	8.300	8	.000
Resistance to pile loop extraction	10 mm	-141.55556	42.56216	14.18739	-174.27173	-108.83938	-9.978	8	.000
	15 mm	-155.08889	41.77991	13.92664	-187.20377	-122.97401	-11.136	8	.000
	20 mm	-150.73333	53.38474	17.79491	-191.76847	-109.69819	-8.471	8	.000
	25 mm	-162.44444	56.73683	18.91228	-206.05623	-118.83266	-8.589	8	.000
Bursting strength		-43.05556	21.07849	7.02616	-59.25792	-26.85319	-6.128	8	.000
Tensile strength		-19.38889	15.76336	5.25445	-31.50568	-7.27210	-3.690	8	.006
Tear strength		571.01111	179.53960	59.84653	433.00476	709.01747	9.541	8	.000
Mass loss ratio		.21111	.49103	.16368	-.16633	.58855	1.290	8	.233
Static water absorption		5.51111	8.43926	2.81309	-.97588	11.99810	1.959	8	.086
Remaining water ratio		18.77778	3.37557	1.12519	16.18309	21.37247	16.689	8	.000

When Table 8 is examined, according to p-value (sig.) it is noticed that, there is a significiant difference at 5% significance level between unwashed and laundered fabrics in terms of the averages of air permeability, resistance to pile loop extraction, bursting strength, tensile strength, tear strength and remaining water ratio test results. This indicates that there is the influence of laundering on these performance properties of woven terry fabrics. The resistance to pile loop extraction, bursting strength and tensile strength increase but the air permeability, tear strength and remaining water ratio decrease after laundering.

4. CONCLUSION

This paper has identified the effects of weft yarn count, weft density and repeated laundering on the air permeability, resistance to pile loop extraction, bursting strength, tensile strength, tear strength, abrasion resistance, static water absorption and drying properties of 100% cotton terry fabrics. Weft yarn count, weft density and repeated launderings are identified as significant factors affecting selected performance properties of terry fabrics.

According to the Tests of Between-Subjects Effects which is obtained from the general linear model analysis weft yarn count parameter is effective on air permeability, resistance to pile loop extraction, bursting strength, tensile strength, tear strength, mass loss ratio and static water absorption and weft density factor is effective on air permeability, resistance to pile loop extraction (15, 20 and 25 mm pulling distances), bursting strength, tensile strength, tear strength, mass loss ratio and remaining water ratio. Fabrics woven with finer weft yarns provide lower resistance to pile loop extraction, bursting strength, tensile strength, tear strength and mass loss ratio but higher air permeability and static water absorption. Lower the weft densities, higher the air permeability and bursting strength but lower the resistance to pile loop extraction, tensile strength, tear strength and mass loss ratio.

The changes in the remaining water ratio in relation to the weft yarn count and the changes in the statics water absobtion in relation to the weft density were not statistically significant. In addition, when analysing the 10 - 25 mm pulling distance, the resistance to pile loop extraction increases.

The statistical evaluations demonstrate that repeated launderings affect the performance properties of woven terry fabrics. It is observed that the resistance to pile loop extraction, bursting strength and tensile strength increase but the air permeability, tear strength and remaining water ratio decrease depending on laundering.

REFERENCES

1. Germanova-Krasteva DS, Kandzhikova GD, Bochev AG. 2013. Influence of terry fabrics structure on dynamic sorption. *International Journal of Clothing Science and Technology* 25(4), 243-256.
2. Zervent B, Çelik N, Koç E. 2003. Havlu dokuma işlemleri ve üretim hesapları. *Tekstil Maraton* 66, 54-60.
3. Singh JP, Behera BK. 2015. Performance of terry towel. *Indian Journal of Fibre&Textile Research* 40, 112-121.
4. Meeren, PV, Cocquyt J, Flores S, Demeyere H, Declercq M. 2002. Quantifying wetting and wicking phenomena in cotton terry as affected by fabric conditioner treatment. *Textile Research Journal* 72 (5), 423-428.
5. Zervent B, Koç E. 2006. An experimental approach on the performance of towels - Part II. Degree of hydrophility and dimensional variation. *Fibres & Textiles in Eastern Europe* 14(2), 64-70.
6. Petrulyte S, Baltakyte R. 2008. Investigation into the wetting phenomenon of terry fabrics. *Fibres & Textiles in Eastern Europe* 16(4), 62-66.
7. Petrulyte S, Baltakyte R. 2009. Static water absorption in fabrics of different pile height. *Fibres & Textiles in Eastern Europe* 17(3), 60–65.
8. Petrulyte S, Nasleniene J. 2010. Investigation of the liquid retention capacity of terry fabrics. *Fibres & Textiles in Eastern Europe* 18(5), 93-97.

9. Sekerden F. 2012. Investigation of water absorbency and color fastness of modal woven towels. *Scientific Research and Essays* 7(2), 145- 148.

10. Zervent Ünal B, Özdemir H. 2013. Experimental and statistical comparison of selected water absorption test methods. *Journal of the Textile Institute* 104(11), 1178–1185.

11. Singh JP, Behera BK. 2014. Performance of terry towel-a critical review. Part I: Water absorbency. *Journal of Textile and Apparel, Technology and Management* 9(1), 1-14

12. Cruz J, Leitão A, Silveira D, Pichandi S, Pinto M, Fangueiro R. 2017, June. Study of moisture absorption characteristics of cotton terry towel fabrics. 3rd International Conference on Natural Fibers: Advanced Materials for a Greener World, Braga, Portugal.

13. Kakde MV, More H, Magarwadia B, Kejkar V. 2017. Effect of pile density on physical properties of terry towel fabric. *International Journal of Textile Engineering and Progress* 3(1), 1-3.

14. Mojsov K. 2018. Enzymatic scouring and bleaching of cotton terry fabrics–opportunity of the improvement on some physicochemical and mechanical properties of the fabrics. *Journal of Natural Fibers* 15(5), 740-751.

15. Singh JP, Behera BK 2018. Designing terry fabric for improved serviceability. *Journal of Fibre&Textile Research* 43, 415-420.

16. Turhan Y, Soydaş Ş. 2018. The effects of ozone bleaching and ozone desizing method on whiteness and water absorption of 100% cotton terry fabrics. *International Journal of Materials Science and Applications* 7(3), 85-94.

17. Rathinamoorthy R. 2019. Influence of repeated household fabric softener treatment on the comfort characteristics of cotton and polyester fabrics. *International Journal of Clothing Science and Technology* 31(2), 207-219.

18. Yıldırım FF, Gelgeç E, Deniz AC, Çörekçioğlu M, Palamutçu S. 2018. The comparison of quick drying characteristics of light-weight warp knitted towels. *MCBÜ Soma Meslek Yüksekokulu Teknik Bilimler Dergisi* 26(II), 45-54.

19. Kurtça E. 2001. Atkı ipliği özellikleri, siklik ve örgü tipinin kumaş mekanik özellikleri üzerine etkisi. İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, İstanbul, 64 s.

20. Omeroglu S, Ulku S. 2007. An investigation about tensile strength, pilling and abrasion properties of woven fabrics made from conventional and compact ring-spun yarns. *Fibres & Textiles in Eastern Europe* 15(1), 39- 42.

21. Zeydan M. 2008. Modelling the woven fabric strength using artificial neural network and Taguchi methodologies. *International Journal of Clothing Science and Technology* 20(2), 104-118.

22. Sarpkaya Ç, Özgür E, Sabır EC. 2015. The optimization of woven fabric tensile strength with taguchi method based on grey relational analysis. *Textile and Apparel* 25(4), 293-299.

23. Vimal JT, Prakash C, Rajwin AJ. 2020. Effect of weave parameters on the tear strength of woven fabrics. *Journal of Natural Fibers* 17(9), 1239-1248.

24. Milašius R, Legaudienė B, Laureckienė G. 2018. Influence of weave parameters on woven fabric tear strength. *Fibres & Textiles in Eastern Europe* 26(4), 48-51.

25. Shanbeh M, Najafzadeh D, Ravandi SAH. 2012. Predicting pull-out force of loop pile of woven terry fabrics using artificial neural network algorithm. *Industria Textila* 63(1), 37-41.

26. Petrulyte S, Dapsauskaite D, Velickiene A, Petrulis D. 2013. Investigation of the resistance to pile loop extraction of linen and ramie fabrics. *Fibres & Textiles in Eastern Europe* 21(5), 54-58.

27. Petrulyte S, Plascinskiene D, Petrulis D. 2017. Testing and predicting of yarn pull-out in aroma-textile. *International Journal of Clothing Science and Technology* 29(4), 566-577.

28. Petrulyte S Baltakyte R. 2008. An investigation into air permeability of terry fabrics regarding the processes of finishing. *Tekstil* 57(1–2), 15–20.

29. Abo-Taleb H, El-Fowaty H, Sakr A. 2015. Theoretical prediction of overall porosity of terry woven fabrics. *Journal of Textile Science & Engineering* 5(6), 217.

30. Petrulyte S, Vankeviciute D, Petrulis D. 2016. Characterization of structure and air permeability of aromatherapic terry textile. *International Journal of Clothing Science and Technology* 28(1), 2-17.

31. Veličkienė A. 2016. Evaluation and forecasting of properties of terry fabrics woven from natural fibres. Summary of Doctoral Dissertation, Kaunas University of Technology, Technological Sciences, Materials Engineering, Kaunas, Lithuania.

32. Zhu G, Fang Y, Zhao L, Wang J, Chen W. 2017. Prediction of structural parameters and air permeability of cotton woven fabric. *Textile Research Journal* 88(14), 1650-1659.

33. Ala DM, İkiz Y. 2017. Subjective and objective evaluations of terry fabrics: Effects of structural parameters and repeated laundering. *Textile and Apparel* 27(4), 361-365.

34. Su CI, Fang JX, Chen XH. 2007. Moisture absorbtion and release of profilled polyester and cotton composite knitted fabrics. *Textile Research Journal* 77, 764-769.

35. Sekerden F. 2018. A study on comparison of air permeability properties of bamboo/cotton and cotton towels. *Scientific Research and Essays* 13, 143-147.

36. Ogulata RT. 2006. Air permeability of woven fabrics. *Journal of Textile and Apparel, Technology and Management* 5(2), 1- 10.

37. Ogulata RT, Mavruz Mezarcioz S. 2012. Total porosity, theoretical analysis, and prediction of the air permeability of woven fabrics. *Journal of The Textile Institute* 103(6), 654-661

38. Zupin Z, Hladnik A, Dimitrovski K. 2012. Prediction of one-layer woven fabrics air permeability using porosity parameters. *Textile Research Journal* 82(2), 117-128.

39. Petrulyte S, Velickiene A, Petrulis D. 2014. Influence of terry fabrics structure and finishing on yarn pull-out behaviour. *International Journal of Clothing Science and Technology* 26(4), 305-315.

40. Teli MD, Khare AR, Chakrabarti R. 2008. Dependence of yarn and fabric strength on the structural parameters. *Autex Research Journal* 8(3), 63-67.

41. Uyanık S. 2016. Investigation of the effect of pile height and yarn linear density on the performance properties of pile loop and cut-pile loop knit fabrics. *Fibres & Textiles in Eastern Europe* 24, 1(115), 95-100.

42. Gabrijelcic H, Cernosa E, Dimitrovski K. 2008. Influence of weave and weft characteristics on tensile properties of fabrics. *Fibers and Textiles in Eastern Europe* 16, 2 (67), 45-51.

43. Chattopadhyay R. 2008. Design of apparel fabrics: role of fiber, yarn and fabric parameters on its functional attributes. *Journal of Textile Engineering* 54, 179-190

44. Kılıç M, Okur A. 2006. Relationships between yarn diameter/diameter variation and strength. *Fibres&Textiles in Eastern Europe* 59, 84-87.

45. Kotb N, El Geiheini A, Salman A, Abdel-Samad A. 2009. Engineering of tearing strength for pile fabrics. *Journal of Textile and Apparel, Technology and Management* 6(1), 1-8.

46. Maqsood M, Nawab Y, Shaker K, Umair M, Ashraf M, Baitab DM, Hamdani STA, Shahid S. 2016. Modelling the effect of weave structure and fabric thread density on mechanical and comfort properties of woven fabrics. *Autex Research Journal* 16(3), 160-164.

47. Şekerden F. 2012. Effect of pile yarn type on absorbency, stiffness, and abrasion resistance of bamboo/cotton and cotton terry towels. *Wood and Fiber Science* 44(2), 189-195.

48. Swani NM, Hari PK, Anandjiwala R. 1984. Performance properties of terry towels made from open-end and ring-spun yarns. *Indian Journal of Textile Research* 9, 90-94.

49. Abd El-Hady RAM, Abd El-Baky RAA, Ali SAS. 2018. Enhancing the functional performance properties of pile weft knitted fabrics used in car interiors. *Journal of Engineering Research and Application* 8(9), 70-81.