Effect of yarn structure variables on comfort properties for cotton towels

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Abstract:
The main purpose of this research is to study the effects of yarn structure variables as key factors influencing the comfort characteristics of cotton towel fabrics. Results of this work can help the producers or manufacturer to create desired quality towel fabric using optimum yarn parameters. The heaviest Grams per Square Meter (GSM) and the highest water vapor permeability were recorded by the Egyptian variety (Giza 90) while the maximum water absorption and air permeability were recorded by the Sudan variety (Acala). It is shown that the mean values of all comfort properties except air permeability decreased when the yarn count and twist multiplier increased. It is obvious that most interaction effects among the yarn parameters (cotton materials, yarn count and twist multiplier) were no significant for all towel comfort properties. It is found negatively and highly significant correlation coefficient between air permeability and each one of the other towel comfort properties. On the other hand, it is indicated that the heavier and thicker towel had more ability to water absorption and water vapor permeability. Also, there was positive and highly significant relation between water absorption and water vapor permeability. Results indicated that there were positively and highly significant associations between yarn hairiness and all towel comfort properties except air permeability. On the contrary, negatively and highly significant associations were obtained between yarn properties being number of neps, thin and thick places and evenness CV % from one side and all towel comfort properties except air permeability from the other side. It is clear that the yarn elongation and yarn tenacity had weak and ineffective effects on the towel comfort properties.

Keywords:
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Cotton Towels
Water Absorption
Air Permeability

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INTRODUCTION

Towels are the most used textile structures in water related usage of terry-woven fabrics. The users prefer towels be more comfortable in terms of light weight, less thick and the lowest air and water vapor permeability. The highest moisture absorption is the great importance parameter of towel performance during end use. Although there are many industrial factors are very important for producing comfortable towels, but the yarn structure parameters play a fundamental role in achieving the desirable quality of towels.

Durur and Öner (2013) showed that the use of the polypropylene fibers for the yarns in high-pile fabrics and the use of the cotton yarn in ground yarns have tend to provide the best comfort.

Singh and Behera (2015) stated that producing highly absorbent terry fabric can be achieved by using longer, finer and hydrophilic fiber to produce soft, bulky, low twisted fine ring-spun pile yarn, further producing terry fabric having high loop density, optimum loop length, high thread density and loop shape factor.

Cruz *et al* (2017) illustrated that terry towel is a fabric with loops on the surface either one or two sides of the fabric that can absorb huge amount of water compared to conventional structure. They added that the moisture absorption related properties of the terry fabrics studied depends up on the fabric weight, thickness and type of pile yarns used (e.g. single, plied or zero-twist).

Abd El-Hady (2018) mentioned that the performance characteristics related behavior of terry towel fabrics were based on their fabric constructions parameters. He found that the towel construction, thickness, weight, the pile height are the towel properties affecting abrasion. High absorbency can be achieved in a towel by increasing the surface area with pile yarns and using microfiber yarns. The absorbency depends on type of fiber, yarn properties, fabric characteristics. The results for bursting strength revealed that the effect of yarn material, knit structure and pile height are highly significant in produced towels.

The present study focused on the assessment of the effect of yarn structure variables (cotton materials, yarn count and twist multiplier) on the comfort properties for cotton towels.

MATERIALS AND METHODS

The comfort parameters of the terry-woven structures in accordance with their usage fields have been identified and in consideration of researched literature the weaving constructions have been arranged and the comfort properties have been examined. The commercial Egyptian cotton varieties Giza 86, Giza 90 and Giza 95 (follow the Long Staple category according to the local practice in Egypt) was chosen to be used as raw material for the current study. The cotton samples were taken from the 2018 crop. Cotton samples were spun using ring spun process system. Three yarn counts (12's, 14's and 16's Ne) and three twist multipliers (3, 3.5, and 4) were applied to study their effects on single yarn mechanical properties and their corresponding towel comfort properties. All fiber and yarn properties were measured under the optimum process conditions at laboratories of Cotton Technology Division of the Cotton Research Institute.

Fibers

The fiber properties being fiber strength at 2.5 span length (mm), uniformity index, fiber strength, fiber elongation %, micronaire reading, and short fiber index were measured by HVI 900 (High Volume Instrument).

Yarns

All towels were made from Ne 24/2 carded cotton form Giza 86 yarn in the ground warp; Ne 16/1 carded cotton form Giza 95 yarn in the ground weft; and Ne (12/1 & 14/1 & 16/1) form using Giza 90, Acala and Medling from Egyptian, Sudan and Greece yarns respectively that produced from staple fibers in the pile. The Cotton fiber properties used are given in Table (1). The yarn properties as affected by cotton materials, yarn count and twist multiplier are given in Table (2).

The STATIMAT automatic tensile tester was used to measure the yarn mechanical properties being single yarn strength cN/tex and yarn elongation %. The test was performed according to the German Standards (DIN-53-834) under controlled atmospheric conditions. Coefficient of variation of the yarn evenness (CV %), number of neps +200/kg, number of thin places -50 % kg, number of thin places +50 % kg and yarn hairiness were measured by the Uster Evenness Tester III as described by the designation of the (A.S.T.M., 1984 D-2256).

Parameter	Giza 95 Weft yarn	Pile warp			Giza 86 Ground warp
		Giza 90	Medling	Acala	
Micronaire, µg/inch	4.5	4.4	5.1	5.3	4.1
Length, mm	30.5	30.7	27.6	25.5	33.9
UI, %	84.8	84.1	80.2	78.6	87.8
SFI	8.11	8.2	10.5	12.82	6.63
Strength, cN/tex	37.9	37.1	32.5	29.6	45.6
Elongation, %	8.2	8.1	6.5	5.6	8.4

Table (1): Summary of average values of six fiber technological properties measured for the used cotton materials.

Towel weaving

It is used 20 picks/cm weft density and 28 ends/cm warp density for Pile/ground. The samples were prepared by considering their variable properties and were classified and evaluated by their characteristics. All of the fabrics were woven with the same weaving design is shown in Figure 1. Formation basic construction in Figure 2.

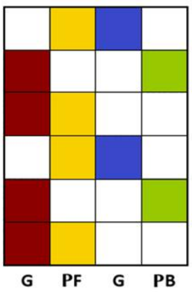

FIGURE 1.

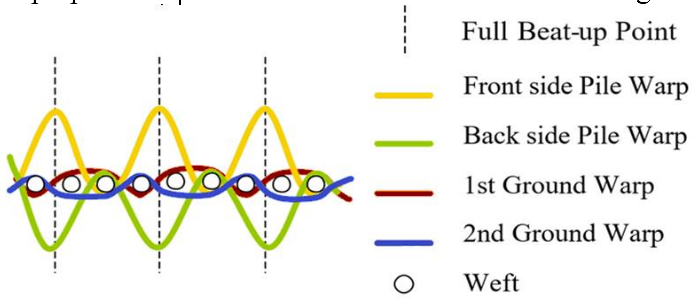

FIGURE 2.

Figure 1. The weaving design used in the samples. G: Ground warp; PF: Face pile warp; PB: Back pile warp & Figure 2. Formation basic construction

Terry Towel		Yarn count		Hairiness, USTER H	Neps +200 % km	Thick places +50 % km	Thin places -50 % km	Evenness CV %	Elongation %	Tenacity cn/tex
Weft yarn		16/1 ring carded		6.6	43	93	49	10.15	6.2	20.51
	Giza 90	12's ring carded Twist multipliers	3	12.9	11	45	5	8.02	8.32	24.90
			3.5	12.5	13	51	7	8.05	8.56	25.12
			4	12.3	16	53	9	8.19	8.75	25.63
	Medling		3	13.8	18	55	10	8.22	7.90	23.42
			3.5	13.3	20	58	12	8.38	7.95	23.63
			4	13.0	23	60	13	8.99	7.99	23.90
	Acala		3	14.9	25	63	15	8.53	7.66	22.06
			3.5	14.7	26	68	19	8.74	7.72	22.73
			4	14.2	28	70	21	8.98	7.85	22.96
	Giza 90	14's ring carded Twist multipliers	3	9.9	30	72	22	9.12	7.31	20.10
			3.5	9.5	33	75	26	9.43	7.62	21.18
			4	9.2	36	77	28	9.54	7.84	21.21
	Medling		3	10.8	47	80	30	9.02	6.32	19.22
			3.5	10.6	48	82	32	9.74	6.56	19.45
			4	10.2	50	48	34	9.96	6.98	19.81
	Acala		3	11.9	55	85	36	10.51	5.21	18.42
			3.5	11.7	58	90	39	10.58	5.75	18.68
			4	11.5	60	91	40	10.22	5.94	18.96
	Giza 90	16's ring carded Twist multipliers	3	6.8	63	93	45	10.16	6.03	19.22
			3.5	6.3	66	95	49	10.05	6.26	20.50
			4	6.0	69	99	51	10.05	6.49	20.86
	Medling		3	7.7	75	103	63	11.60	5.61	18.22
			3.5	7.5	78	117	69	11.82	5.72	18.90
			4	7.2	74	121	78	11.95	5.81	18.99
	Acala		3	8.9	81	132	82	13.93	5.32	17.15
			3.5	8.6	83	135	89	14.53	5.50	17.32
			4	8.1	86	152	96	14.94	5.63	17.95
Ground warp		24/2 ring carded		5.1	78	119	88	18.22	7.01	17.80

Table (2): Summary of average values of seven yarn properties as affected by cotton materials, yarn count and twist multiplier.

Loom and Finishing Process

The samples were woven in Picanol-Gamma-8-J (1998) dobby type towel weaving machines. The machine width was 190 cm with 4 pile frames having 8 weft insertion, 8 ground frames and 2 leno weaving frames with 16 frames. The bleaching process applied to cotton towels was used in towel samples in order to have repetitive towels like those selling in the market. No finishing process was applied for samples. The fabrics were treated with optical bleaching in the overflow machines.

Test method

Air permeability tests were made with TEXTTEST FX 3300 air permeability test equipment. According to ISO 9237 test standards, the test pressure for the normal fabrics is 100 Pa, the applied 20 cm2 test area and the measuring unit is mm/s. Water vapor permeability test was made with M261 Shirley water vapor permeability test equipment. The test was made in accordance with ISO 15496 test standards. The measuring unit is g/m2 /24h. The measuring of the velocity of soaking of textile fabrics in respect of water –also called the increasing level or liquid transfer velocity- was made in accordance with DIN 53924 standards under laboratory conditions which are 20±2 0 C and 65% relative humidity. The measurements were reported within in 60 seconds measurement time in both warp and weft directions.

Statistical analysis

The collected data were analyzed using analysis of variance (ANOVA) with three factors (cotton materials, yarn count and twist multiplier) to obtain their main effects and their interactions according to the procedure proposed by **Snedecor and Cochran (1989).** Least significant difference (L.S.D.) at 5 % level of probability was used to compare the tested treatments means. Simple correlation coefficients among towel comfort properties were computed. In addition, the associations between each one of the towel comfort properties and the yarn properties were obtained according to **Snedecor and Cochran (1989).** SPSS version 13 (SPSS, 2004) and Minitab version 14 (2005) statistical packages were used to automate the previous statistical analyses.

RESULTS AND DISCUSSION

From the comfort properties point of view, the standard performance towel was enjoyed by light weight (low Grams per Square Meter, GSM), less thick and the lowest air and water vapor permeability. The highest moisture absorption property is the great importance of towel performance during end use.

The effect of yarn structure variables on comfort properties

Table (3) contained the average values of comfort properties for towel as affected by cotton materials. There were significant differences among the used cotton materials for all comfort properties except thickness. The highest mean values of Grams per Square Meter (GSM) and water vapor permeability were recorded by the Egyptian variety (Giza 90) followed by the Greece variety (Medling) and then the Sudan variety (Acala). On the contrary, the maximum mean values of water absorption and air permeability were recorded by the varieties Acala followed by Medeling and then Giza 90. The thickness mean values ranged from 15.93 mm for Acala variety to 16.47 mm for Giza 90 with no significant differences among the three cotton materials. The differences among the used cotton materials for most comfort properties may be attributed to the genetic origin, fiber nature and cellulosic content.

Habib (2015) cleared that the advantage of cottons fibers is the highest absorption capacity, of the material that used for terry towels, this is due to the hydrophilic, but cottons disadvantage is that the fibers swell of water, the swelling reduces the wicking rate. A hydrophobic and hydrophilic fiber can work together. The hydrophilic fabric can absorb the liquid and then the hydrophobic will help the liquid to evaporate.

Table (3): The average values of comfort properties for towel as affected by cotton materials.

Cotton materials	Comfort properties				
	(GSM) (g/m^2)	Thickness (mm)	Water Absorption (mm/60s)	Air Permeability (mm/s)	Water Vapor Permeability (g/m^2/24h)
Giza 90	525.61	16.47	37.68	222.69	515.60
Medling	517.61	16.32	40.52	226.63	508.91
Acala	507.26	15.93	43.28	228.49	504.39
LSD $_{0.05}$	0.99	NS	0.76	0.97	1

The change in yarn count influencing the comfort properties for towel was illustrated in Table (4). Results revealed that all comfort properties for towel were significantly affected by the change in yarn count (12's, 14's and 16's Ne). It is shown that all comfort properties except air permeability were significantly decreased when the yarn count increased from 12's to 16's Ne. This result indicates that there are negative associations between yarn count and most comfort properties. In accordance, the lowest mean values of all comfort properties except air permeability were recorded by using the finer yarns. It was found that using coarse yarns will increase the surface area of pile yarns, which increasing the water absorption; due to the towel has the ability to pick up more water**. Yildirim *et al* (2018)** stated that although high weighted towels absorb more water, they need too much time for washing and drying processes which cause more energy consumption. Light-weighted towels are washed and dried easily compared to their high weighted counterparts.

Kotb (2012) appeared that the air permeability property seemed to be higher when yarns became finer while the thickness tended to be decreased. He added that the increase in thickness of yarn caused a decrease in air permeability. **Tusief *et al.* (2017)** stated that increasing the yarn count from 12's to 20's was significantly increased the air permeability indicating that there direct relationship between the yarn count and air permeability. They added that, for the same fabric weight (g/m^2), the finer yarn give better fabric cover than the coarser yarn due to higher number of yarn per unit area of fabric, which directly affects the air permeability of the fabric.

Table (4): The average values of comfort properties of towel as affected by yarn count.

Yarn count	Comfort properties				
	(GSM) (g/m^2)	Thickness (mm)	Water Absorption (mm/60s)	Air Permeability (mm/s)	Water Vapor Permeability (g/m^2/24h)
12's Ne	567.15	18.10	47.76	216.06	533.82
14's Ne	514.56	15.95	42.18	226.03	511.82
16's Ne	468.78	14.66	31.54	235.72	483.26
LSD $_{0.05}$	0.99	0.61	0.76	0.97	1.00

The main effect of twist multiplier on the comfort properties for towel is tabulated in Table (5). Significant differences were obtained among the three twist multipliers (3, 3.5 and 4) for all the comfort properties of towel except thickness. The thickness average values ranged from 16.21 mm for twist multiplier 3 to 16.27 mm for twist multiplier 4 with no significant differences among them.

It is clear all the mean values comfort properties for towel decreased as a result of increasing the twist multiplier from 3 up to 4. The reversed trend was true for air permeability, where they tended to increase with the increase in twist multiplier. Subsequently, there are negative trend between twist multiplier and all the comfort properties for towel except air permeability. It is concluded that, as the twist multiplier increases, it will reduce the fiber movement inside the cross section, which does not allow a large amount of water to be absorbed. **Sekerden (2015)** indicated that the towels woven with twistless pile yarns have greater absorptive capacity, longer absorbency time, and lower flexural rigidity than towels woven with twisted pile yarns.

Table (5): The average values of comfort properties for towel as affected by twist multiplier.

Twist multiplier	Comfort properties				
	(GSM) (g/m^2)	Thickness (mm)	Water Absorption (mm/60s)	Air Permeability (mm/s)	Water Vapor Permeability (g/m^2/24h)
3	518.40	16.27	41.61	225.11	511.13
3.5	517.05	16.23	40.51	225.88	509.82
4	515.03	16.21	39.36	226.82	507.94
LSD $_{0.05}$	0.99	NS	0.76	0.97	1

Considering the twist multiplier factor was held constant, the average values of comfort properties for towel as affected by the interaction effect between cotton materials and English yarn count are presented in Table (6).

Results revealed that the interaction effect between cotton materials and English yarn count was significance for all towel comfort properties except thickness and air permeability. Accordingly, this result stated that the effect of yarn counts on thickness and air permeability was relatively similar under the used cotton materials. Subsequently, overall used cotton materials, it is shown that thickness was decreased when the yarn count increased from 12's to 14's Ne while the reverse trend held true for air permeability which was increased. This result indicates that using more fine yarns will give a less thick and more air permeable towel.

With respect to Grams per Square Meter, water absorption and water vapor permeability, they were generally decreased when the yarn count increased from 12's to 16's Ne. But the significant interaction effect means that they are differently responded for increasing yarn count under different cotton materials. For instance, when using the Egyptian variety of Giza 90 with increasing the yarn count from 12's up to 14's and then 16's, it is revealed that the Grams per Square Meter, water absorption and water vapor permeability were decreased by (10.71 and 18.52 %), (16.66 and 40.11 %) and (4.14 and 9.72 %), respectively. While with using Sudan variety (Acala), the corresponding percents decreased by (12.73 and 20.87 %), (9.07 and 27.40 %) and (4.06 and 9.18 %), respectively with increasing the yarn count from 12's up to 140's and 16's. **Tusief (2017)** depicted that finer count and increased share of polyester in the blend put negative impact on the comfort related properties of the polyester /cotton plain knitted fabric. **Yilmaz and Powell (2005)** presented an important article summarized the basis for understanding the main steps for producing a high quality woven terry fabric.

Table (6): The average values of comfort properties for towel as affected by the interaction effect between cotton material and yarn count.

Cotton materials	Yarn count	Comfort properties				
		(GSM) (g/m^2)	Thickness (mm)	Water Absorption (mm/60s)	Air Permeability (mm/s)	Water Vapor Permeability (g/m^2/24h)
Giza 90	**12's Ne**	582.35	17.87	46.47	213.50	540.57
	14's Ne	519.99	16.68	38.73	223.10	518.20
	16's Ne	474.50	14.85	27.83	231.47	488.03
Medling	**12's Ne**	566.84	18.13	47.53	216.50	533.23

	14's Ne	515.47	16.16	43.00	226.93	511.00
	16's Ne	470.51	14.67	31.03	236.47	482.50
Acala	**12's Ne**	552.25	18.30	49.27	218.17	527.67
	14's Ne	508.22	15.01	44.80	228.07	506.27
	16's Ne	461.32	14.47	35.77	239.23	479.23
LSD $_{0.05}$		1.73	NS	1.32	NS	1.74

Results in Table (7) presented the mean values of towel comfort properties as affected by the first-order interaction effect between twist multiplier and the used cotton materials considering the yarn count was held constant. The interaction effect between twist multiplier and cotton materials was not significant for all towel comfort properties indicating that the effect of twist multiplier followed similar trend under all used cotton materials.

Looking at Table (7), overall cotton materials; it is clear that Grams per Square Meter, thickness and water vapor permeability decreased with each increment in twist multiplier (negative relation). Accordingly, irrespective of the cotton materials, it could be concluded that the preferable performance of the above three towel comfort properties were obtained with increasing the twist multiplier to the optimum level. Considering each of water absorption and air permeability, it is concluded that the towel characterized by high water absorbent and less air permeability would be produced under the lowest twist multiplier equal 3.

Table (7): The average values of comfort properties for towel as affected by the interaction effect between cotton material and twist multiplier.

Cotton materials	Twist multiplier	Comfort properties				
		(GSM) (g/m^2)	Thickness (mm)	Water Absorption (mm/60s)	Air Permeability (mm/s)	Water Vapor Permeability ($g/m^2/24h$)
Giza 90	**3**	526.57	16.51	38.57	221.33	517.80
	3.5	525.64	16.46	37.93	222.57	515.97
	4	524.63	16.43	36.53	224.17	513.03
Medling	**3**	520.21	16.34	41.93	225.90	510.37
	3.5	518.23	16.32	40.20	226.70	508.90
	4	514.38	16.30	39.43	227.30	507.47
Acala	**3**	508.41	15.96	44.33	228.10	505.23
	3.5	507.28	15.91	43.40	228.37	504.60
	4	506.09	15.91	42.10	229.00	503.33
LSD $_{0.05}$		NS	NS	NS	NS	NS

Results of the first-order interaction effect between yarn count and twist multiplier on towel comfort properties are presented in Table (8). It is shown that the interaction effect was not significant for all towel comfort properties indicating that the effect of twist multiplier on all towel comfort properties was relatively similar regardless the used yarn count. For any yarn count, it is appeared that the lowest values of all towel comfort properties except air permeability were recorded by increasing the twist multiplier from 3 up to 4 confirming the negative relationships between twist multiplier and each one of the aforementioned towel comfort properties. On the other hand, the mean values of air permeability were increased with increasing twist multiplier at any yarn count. Accordingly, the towels characterized with the lightest weight (Grams per Square Meter) and less thickness as well as the lowest air permeability and water vapor permeability were produced by finer yarns with high twist multiplier. **Singh and Behera (2014)** wrote an article provides a collective source of information to understand the philosophy of absorbency and the ways to develop highly absorbent terry fabrics.

Table (8): The average values of comfort properties for towel as affected by the interaction effect between yarn count and twist multiplier.

Yarn count	Twist multiplier	Comfort properties				
		(GSM) (g/m^2)	Thickness (mm)	Water Absorption (mm/60s)	Air Permeability (mm/s)	Water Vapor Permeability ($g/m^2/24h$)
12's Ne	**3**	569.84	18.08	48.47	215.20	535.43
	3.5	567.87	18.09	47.73	216.17	533.93
	4	563.73	18.12	47.07	216.80	532.10

14's Ne	3	515.47	15.99	43.03	225.43	513.50
	3.5	514.45	15.94	42.10	225.97	512.03
	4	513.76	15.92	41.40	226.70	509.93
16's Ne	3	469.88	14.74	33.33	234.70	484.47
	3.5	468.84	14.66	31.70	235.50	483.50
	4	467.61	14.59	29.60	236.97	481.80
$LSD_{0.05}$		NS	NS	NS	NS	NS

Results of the second-order interaction effect among the three studied factors (cotton materials, yarn count and twist multiplier) on towel comfort properties are presented in Table (9). It is revealed that the interaction effect was no significant for all towel comfort properties indicating that each one of the three studied factors reflect similar behavior under the other two variables. Across the two factors of yarn counts and twist multipliers, it is apparent that the lightest weight of Grams per Square Meter, less thick and more water permeable towel were obtained by Sudan variety (Acala) followed by Greece variety (Medling) and Egyptian variety (Giza 90). However, irrespective of the used cotton materials and twist multiplier, it was found that using finer yarns will decrease the surface area of pile yarns which decrease the water absorption; due to the weak ability of towel to pick up more moisture. Also, the weight and thickness of towel were decrease as the yarn count increased. On the other hand, it is obvious that all the comfort properties except air permeability for towel decreased as a result of increasing the twist multiplier overall cotton materials and yarn count used in this study. **Ramachandran (2015)** described that cotton is used for toweling because it is the most economical fiber among the natural fibers. Shorter staple cotton fibers are generally used in towels because fine yarn counts are not required. The cotton fibers which are used in towels have relatively low fiber length, and relatively low maturity ratio. The Micronaire range can be said to be in the middle range.

Table (9): The average values of comfort properties for towel as affected by the interaction effect among cotton material, yarn count and twist multiplier.

Factors			Comfort properties				
Cotton materials	Yarn count	Twist multiplier	(GSM) (g/m^2)	Thickness (mm)	Water Absorption (mm/60s)	Air Permeability (mm/s)	Water Vapor Permeability ($g/m^2/24h$)
Giza 90	12's Ne	3	583.32	17.96	46.80	212.30	542.60
		3.5	582.67	17.85	46.50	213.70	540.40
		4	581.05	17.81	46.10	214.50	538.70
	14's Ne	3	521.40	16.65	39.10	221.90	520.60
		3.5	519.61	16.69	38.90	222.80	518.70
		4	518.97	16.71	38.20	224.60	515.30
	16's Ne	3	474.98	14.92	29.80	229.80	490.20
		3.5	474.65	14.84	28.40	231.20	488.80
		4	473.87	14.78	25.30	233.40	485.10
Medling	12's Ne	3	572.55	18.05	48.70	215.40	535.30
		3.5	568.78	18.14	47.30	216.70	533.50
		4	559.20	18.19	46.60	217.40	530.90
	14's Ne	3	516.32	16.25	44.70	226.50	512.40
		3.5	515.73	16.15	42.50	227.00	510.90
		4	514.36	16.09	41.80	227.30	509.70
	16's Ne	3	471.76	14.73	32.40	235.80	483.40
		3.5	470.19	14.68	30.80	236.40	482.30
		4	469.57	14.61	29.90	237.20	481.80
Acala	12's Ne	3	553.64	18.23	49.90	217.90	528.40
		3.5	552.17	18.29	49.40	218.10	527.90
		4	550.93	18.37	48.50	218.50	526.70
	14's Ne	3	508.70	15.08	45.30	227.90	507.50
		3.5	508.01	14.99	44.90	228.10	506.50

		4	507.95	14.96	44.20	228.20	504.80
	16's Ne	**3**	462.90	14.57	37.80	238.50	479.80
		3.5	461.67	14.46	35.90	238.90	479.40
		4	459.39	14.39	33.60	240.30	478.50
LSD $_{0.05}$			**NS**	**NS**	**NS**	**NS**	**NS**

The associations among comfort properties of cotton towel.

The Correlation coefficients among all towel comfort properties overall studied factors are summarized in Table (10). Results indicated that there highly significant associations among the towel comfort properties. It is found negatively and highly significant correlation coefficient between air permeability and each one of the other towel comfort properties indicating the cotton towel which is more weight and thicker would be low air permeable. As well as**,** when the towel's ability to absorb water and water vapor permeability is increased, its ability toward air permeability would be decreased. On the other hand, there were highly significant and positively associations between Grams per Square Meter and thickness and each of water absorption and water vapor permeability indicating that the heavier and thicker towel had more ability to water absorption and water vapor permeability. In the same context, there was positive and highly significant relation between water absorption and water vapor permeability. Therefore, the towel producers must be aware with the interrelationships among desirable and undesirable comfort properties.

Table (10): Correlation coefficients among all towel comfort properties overall studied factors.

Towel comfort properties	GSM	Thickness	Water Absorption	Air permeability	Water vapor permeability
(GSM)	1				
Thickness	0.803**	1			
Water absorption	0.832**	0.680**	1		
Air permeability	-0.964**	-0.768**	-0.756**	1	
Water vapor permeability	0.986**	0.796**	0.832**	-0.967**	1

**: significant at 0.01 probability level.

The associations among cotton towel comfort properties and its corresponding yarn properties.

The correlation coefficients among towel comfort properties and its corresponding yarn properties overall studied factors are tabulated in Table (11). Results indicated that there were positively and highly significant associations between yarn hairiness and all towel comfort properties except air permeability indicating that using more hairy yarn would increase the weight, thickness and water absorption of the cotton towel while the air permeability would be decreased. On the contrary, negatively and highly significant associations were obtained between yarn properties being number of neps, thin and thick places and evenness CV % from one side and all towel comfort properties except air permeability from the other side. The current results stated that when the yarn imperfections increase, the quality properties of the manufactured cotton towel would be decreased. Although the relationships between both of yarn elongation and yarn tenacity, and the towel comfort properties were significant, but the correlation coefficients were less than 0.6 indicating that the of yarn elongation and yarn tenacity had weak and ineffective effects on the towel comfort properties. **Parsi (2015)** illustrated that cotton is the king of fiber, fabric produced from 100 % cotton is quite expensive but in the market on different trade names regenerated fibers are also available which gives better hand feel properties than cotton. If manufacturer used these fibers in the production of terry fabrics, that would give better scope for terry products.

Table (11): Correlation coefficients among the towel comfort properties and their corresponding yarn properties.

Yarn properties	Towel comfort properties				
	GSM	**Thickness**	**Water Absorption**	**Air permeability**	**Water Vapor permeability**
Hairiness	0.694**	0.636**	0.591**	-0.711**	0.702**
Number of neps	-0.665**	-0.630**	-0.696**	0.606**	-0.636**
Thin places (+50 % km)	-0.620**	-0.559**	-0.759**	0.552**	-0.607**

Thin places (-50 % km)	-0.680**	-0.637**	-0.762**	0.618**	-0.670**
Evenness CV %	-0.625**	-0.571**	-0.761**	0.528**	-0.606**
Elongation %	0.497*	0.462*	0.521**	-0.412*	0.432*
Tenacity	0.484*	0.492*	0.514**	-0.404*	0.430*

CONCLUSION

The towel comfort properties as influenced by three yarn structure variables being cotton materials, yarn count and twist multiplier, and their all interaction effects are studied and discussed in the present investigation. Results indicated that there were significant differences among the used cotton materials for all comfort properties except thickness. However, result indicates that there are negative associations between yarn count and most towel comfort properties. It is clear all towel comfort properties except air permeability were decreased as a result of increasing the twist multiplier from 3 up to 4. It is revealed that most the interaction effects were no significant for all towel comfort properties indicating that each one of the three yarn structure variables reflect similar behavior under the other two factors.

It is found negatively and highly significant correlation coefficients between air permeability and each one of the rest towel comfort properties. On the other hand, there were positively and highly significant associations between Grams per Square Meter and thickness, and each of water absorption and water vapor permeability. Results indicated that there were positively and highly significant associations between yarn hairiness and all towel comfort properties except air permeability. On the contrary, negatively and highly significant associations were obtained between yarn properties being number of neps, thin and thick places and evenness CV % from one side and all towel comfort properties except air permeability from the other side.

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