

Effects of the Laundering Process on Dimensional and Physical Properties of Plain and Lacoste Fabrics Made from Modal/Combed Cotton Blended Yarns

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Abstract

In this study, dimensional and some physical properties of plain (single jersey) and lacoste knitted fabrics made from 50/50 modal/combed cotton blended yarns (tex 21 and 15) were investigated. Twelve weft knitted fabrics were produced with two different structures and three different densities (loose, medium, tight). For physical properties, the fabric weight per unit area, fabric thickness, bursting strength, air permeability and dimensional stability were evaluated. We focused on the dimensional stability properties of outwear knitted fabrics. The total dimensional change of the fabric's dimensions and structural properties were measured and evaluated after ten washing cycles and then flat dried. The results show that the weight per unit area, thickness, air permeability and dimensional stability values are independent of the yarn linear density, fabric structure and fabric density. Statistically evaluated using Design Expert Analysis of variance (ANOVA) software 6.06., test results show that dimensional stability is mostly effective for the bursting strength, air permeability and fabric weight per unit area.

Key words: modal/combed cotton fibres, washing cycle, air permeability, dimensional stability, bursting strength.

■ Introduction

Knitted fabrics are commonly used because of their excellent mechanical and comfort properties. The advantages of using knitted fabrics, as opposed to conventional fabrics, lie in their low cost, improved barrier properties, adequate strength and comfort properties. During the knitting process, the yarns in the fabric are constantly under stress. As a result, the fabric on the machine is more distorted than in its natural relaxed state. When the fabric is removed from the machine, it has time to relax and overcome these stresses, a form of relaxation that is easily recognizable by the changes in dimensions [1]. It is well known that weft knitted fabrics tend to undergo large changes in dimensions and are often prone to distortion upon repeated laundering. A large number of factors are responsible for causing these undesirable effects in knitted structures; these are all associated with the yarn, knitting, finishing and making-up of the fabrics. It is also a fact that consumers are becoming increasingly concerned and aware of fabric quality and expect higher standards of performance than ever before, even after a number of wash and dry cycles [2].

Many properties help to determine fabric quality, and consequently the quality of apparel or other products in which the fabrics are used. Textile products are tested at various stages of production to assure quality processing and products. A common problem with knitted textile products is the development of dimensional change after laundering, which is also an element of fabric quality. To obtain the dimensional stability of knitted fabric: for the purpose of wearing comfort and fabric appearance, the knitted fabric's original shape and resistance to flexibility, shrinkage and loosening need to be protected.

Many studies have reported the results of judging the objective hand of fabrics based on their mechanical and dimensional properties, Choi et al. [3] investigated the mechanical properties of weft knits for outwear as a function of the knit structure and density, and the relationships between hand, structure and density. Fatkic et al. [4] studied the influence of selected knitting parameters and the relaxation period on the structure and mechanical properties of plain jersey weft knitted fabrics made of cotton and elastane yarns, with the conclusion that the feeding load of yarns should be taken into account when constructing knitted fabrics as it considerably affects fabric properties. Gun [5] evaluated the dimensional, physical and thermal

comfort properties of plain knitted fabrics made from a 50/50 blend of modal viscose fibre in a microfibre form with cotton fibre compared with those of similar fabrics made from a 50/50 blend of conventional modal viscose fibre with cotton fibre and one made from 100 % cotton fibre. Others have reported that the mechanical properties of knitted fabrics vary according to knit structure, fibres, yarns and densities, which, in turn, affect the knit's hand significantly. Gun [6] investigated the dimensional and some physical and thermal comfort properties of plain knitted fabrics made from modal viscose yarns with microfibre. The results were then compared with those of similar fabrics made from conventional modal viscose yarns with the help of statistical analysis. Mikucioniene et al. [7] undertook an investigation of the influence of the knit structure, yarn linear density, loop length and the tightness factor of the knit on garment flammability and permeability to air. Bivainyte and Mikucioniene [8] investigated the influence of knitting structure parameters and raw materials on the air and water vapour permeability of double layered knits used for leisure sports. The main influence on the water vapour permeability of double layered knitted fabrics is the kind of raw material i.e. the wetting and wicking properties of fibres. An investigation of the effect of raw material on the water vapor resistance of 100% cotton, 50-50%

Table 1. Properties of yarns of knitted fabrics.

Modal %50 / Combed cotton %50	Yarn linear density, tex	
	21	15
Number of twists, turns/m	790	909
Coefficient of variation of mass, %CVm	11,81	12,27
Thin places, -% 50/km	0	2
Thick places, +% 50/km	15	10
Neps, +% 200/km	26,5	24
Tenacity, cN/tex	15,3	14,81
Breaking force, cN	226	218
Elongation at break, %	6,12	5,97
Hairiness, H	6,47	5,63

cotton-modal, 100% viscose and 100% tencel fabrics, which had the same knit construction and similar constructional parameters, was conducted by Skenderi et al. [9], where cotton and cotton modal fabrics showed similar behaviour to each other. Gun et al. [10] studied the dimensional and some physical properties of plain knitted fabrics made from 50/50 bamboo/cotton blended yarns. The results show that the weight, thickness, dimensional changes, bursting strength and air permeability values are independent of the fibre type. Duru and Candan [11] established that good moisture transport and drying properties are quite important factors for garments worn next to the skin, especially sportswear, underwear, etc., and seamless technology, in comparison to circular knitting technology, may offer higher flexibility in designing such garments with optimized comfort properties. Some researchers describe the relation between the knitting parameters and mechanical properties of knitwear. Dimensional control of knitted fabrics has always been a serious problem for knitwear.

Due to the influence of fashion, the production of knitted goods has been expanded, with new fabric designs created with different fibre blends and knit structures. The effect of the former on fabric shrinkage has been extensively investigated in various combinations, but as far as the latter is concerned, there is still a lack of information in the literature. The dimensional change of fabrics, especially due to repeated laundering, is a critical attribute, and hence its accurate quantification is a major concern for all sectors of the textile industry. In this study, examined were the effects of domestic laundering on plain and lacoste knitted fabrics made of modal/combed cotton blend yarn over a large number of wash cycles, which was also undertaken

to identify damaging aspects of the laundering process.

Experimental

Modal fibre is one of the regenerated cellulose fibres, obtained by a process giving high tenacity and high wet modulus. Modal fibre has a gentle, comfortable handle, is lustrous, and has high wet and dry tensile strength fastness values formed in the yarn features of cotton fibre's known characteristics [12].

In this study, 50/50 modal (Lenzing, Austria) combed cotton (Greece) blended yarns were used. The modal fibre fineness was 1.2 dtex and the fibre length 38 mm. Combed cotton fibre properties were as follows: fibre length 29 mm and fibre fineness 1.77 dtex. Properties of the yarns are given **Table 1**.

Plain (single jersey) and lacoste knitted fabrics were produced on an E28 gauge Terrot circular knitting machine (Germany) with 30 inch diameter and 96 feeders. Sample fabrics were produced in three different stitch lengths, such as tight, medium and loose knitted fabrics. All experiments were carried out in a standard atmosphere according to standard ISO 139 [13]. The following properties of the sample fabrics were measured before and after washing cycles in accordance with relevant standards: course per cm and wale per cm TS EN 14971 [14], stitch length TS EN 14970 [15], and weight per unit areas in g/m² EN 12127 [16]. The number of wales per cm and that of courses per cm were determined by taking ten measurements from different areas of each fabric. Afterwards mean values were calculated. The product of these means was used to determine the stitch density of a sample. Stitch length measurements were made by taking yarns from 100 stitch-

es in the same course and then hanging a 10 g weight on the yarns. Mean values of the stitch length were calculated for each fabric. Samples were washed ten times at 40 °C for 50 minutes and then dried. The measurements were repeated after the washing cycles. Dimensional properties of the plain knitted fabrics were determined by calculating the dimensional constant, as introduced by Doyle and Munden [17, 18]. Results of the fabric dimensional parameters such as courses/cm, wales/cm, stitches/cm² and courses/wales are given in **Table 2**.

The following properties were measured before and after the washing cycles, in accordance with the relevant standards: fabric thickness ISO 9238 [19], bursting strength ISO 12945-2 [20] and air permeability ISO 9237 [21]. Thickness, bursting strength and air permeability measurements were made on a Shirley thickness gauge (USA), James Heal TruBurst bursting strength tester (UK) and SDL Atlas air permeability testers (USA), respectively. Fabrics were fully conditioned for 48 hour in a standard atmosphere of 20 °C and 65% relative humidity. The specimens to be tested for dimensional stability were prepared as recommended in EN ISO 6330 and EN ISO 5077 [22, 23]. A dimensional stability test was performed with a standard household washing machine.

Statistical evaluation of the data obtained was performed with a design expert analysis package program 6.06 software package. One way analysis of variance (ANOVA) was employed and the factors were considered to be significant at a p-value of less than 0.005. Statistical analysis was used to identify the relationships between dimensional parameters and the stitch length. The effects of the fibre type and stitch length on the weight per unit area, thickness, bursting strength, air permeability and dimensional stability properties of the plain (single jersey) and lacoste knitted fabrics were investigated.

Results and discussion

Our main objective in this study was to investigate plain (single jersey) and lacoste knitted fabrics made from a modal/combed cotton blend after a large number of washing cycles and identify damaging aspects of the laundering. Moreover how similar the modal/combed cotton blend

knitwear fabrics constructed were when subjected to up to ten laundering cycles in a variety of washing and drying conditions was described.

Fabric dimensional properties

Stitch length was a major factor which affected all the other properties i.e. wales per cm, courses per cm and the tightness factor. **Table 2** shows that for each fabric type, the courses/cm and stitches/cm² decrease with an increasing stitch length, as expected. The same tendency can also be observed between the wales/cm and stitch length. However, variation in the stitch length seems to have little or no effect on the wales/cm. During the knitting process, the loops are under the effect of continuous internal stresses, especially in the wale direction; however, this effect is diminished when the fabric is relaxed. This change is considered to be less because the internal tension is lower in the number of wales.

Fabric weight

The weight per unit area of knitted fabrics depends on the structure, yarn linear density and dimensional properties of the knitted fabrics. When the fabric's density is more, the fabric's weight is also higher. From the weight results in **Figure 1**, it can be observed that that of the raw fabrics decreases with an increase in the stitch length, because of the increase in the stitch length decreasing the number of stitches.

Fabric thickness

The thickness of the knitted fabric depended on the yarn linear density, structure and relative closeness of the loops.

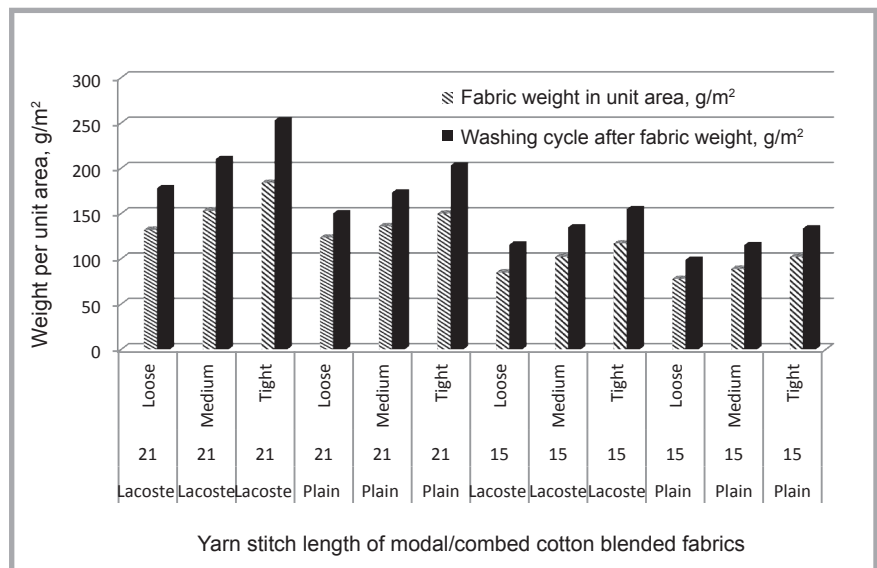


Figure 1. Effect of weight per unit area of modal/combed cotton blended fabrics.

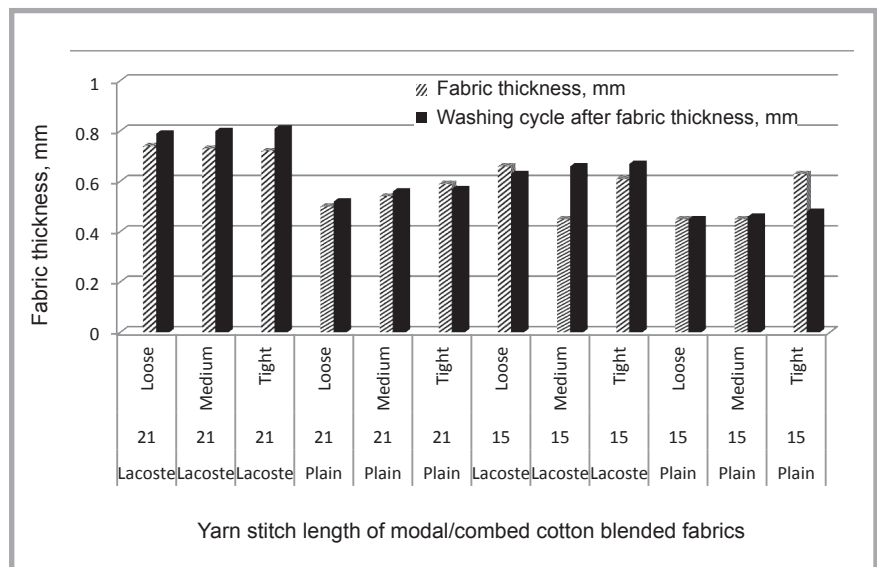


Figure 2. Effect of fabric thickness of modal/combed cotton blended fabrics.

Table 2. Dimensional parameters of plain and lacoste knitted fabrics.

Fabric types	Yarn linear density, tex	Fabric density	Dimensional Parameters									
			Stitch length, mm		Course density, course/cm		Wale density, wale/cm		Stitch density, cm ²		Courses/Wales	
			Before	After	Before	After	Before	After	Before	After	Before	After
Lacoste	21	Loose	0.28	0.30	20	20	11	10	220	200	1.81	2
Lacoste	21	Medium	0.25	0.26	22	25	11	11	242	275	2	2.27
Lacoste	21	Tight	0.24	0.23	22	29	11	14	242	406	2	2.07
Plain	21	Loose	0.30	0.30	16	18	13	12	208	216	1.23	1.5
Plain	21	Medium	0.28	0.27	19	21	13	15	247	315	1.46	1.4
Plain	21	Tight	0.24	0.25	24	24	13	16	312	384	1.85	1.5
Lacoste	15	Loose	0.30	0.29	18	22	10	11	180	242	1.80	2
Lacoste	15	Medium	0.28	0.26	20	22	10	11	200	242	2	2
Lacoste	15	Tight	0.24	0.23	22	24	11	12	242	288	2	2
Plain	15	Loose	0.29	0.30	15	24	13	15	195	360	1.15	1.6
Plain	15	Medium	0.28	0.27	18	18	13	15	234	270	1.38	1.2
Plain	15	Tight	0.26	0.24	22	18	13	13	286	234	1.69	1.38

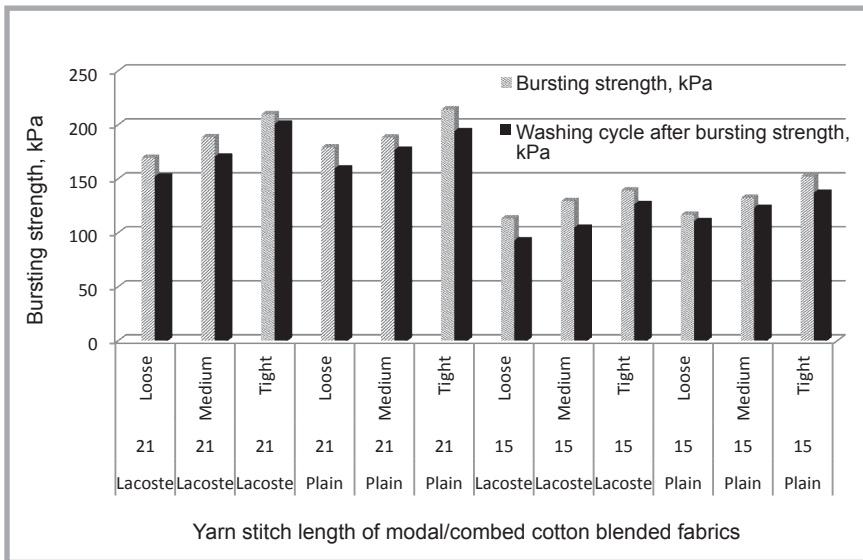


Figure 3. Effect of the bursting strength of modal/combed cotton blended fabrics.

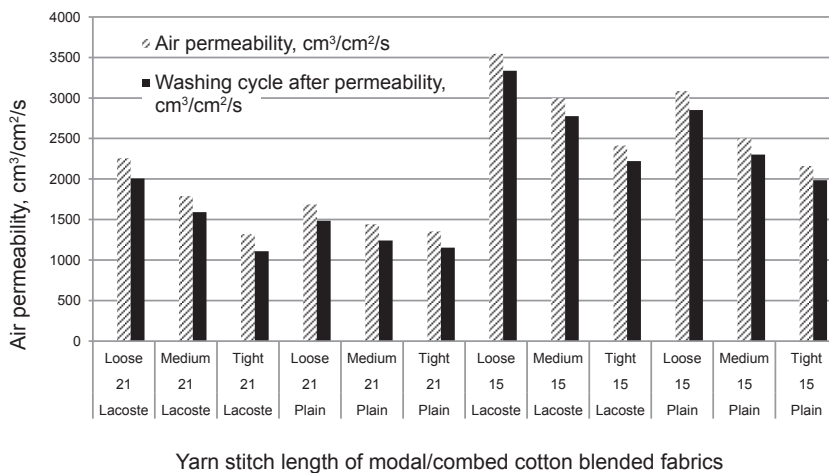


Figure 4. Effect of air permeability of modal/combed cotton blended fabrics.

The results in *Figure 2* show that the fabric thickness does not seem to change with the stitch length. However, in the full relaxation state, the fabric thickness increases with a decrease in the stitch length. The highest thickness results are obtained for lacoste knitted fabrics. As a result of statistical analysis, the fabric structure, yarn linear density and fabric density were determined as having no effect on the fabric thickness.

Both of the single jersey and lacoste knitted fabrics are of a plain knitted structure. Due to the structure pattern, lacoste knitted fabrics are coarser than single jersey knitted fabrics; but there is no significant difference in thickness between them.

Bursting strength

Bursting strength is a measure of the strength of material stressed in all directions. It was tested with the help of a bursting strength tester at ten different places per sample, with the reading noted in kPa. Bursting strength results of the raw fabrics shown in *Figure 3* reveal that plain and lacoste knitted fabrics have been found to have the highest bursting strength of tightly knitted structure which is made of yarn linear density of 21 tex. The bursting strength results of the fabrics tend to decrease with an increase in the stitch length. As the stitch length increases, stitch density values of the fabric also decrease. Therefore the lower number of stitches match the bursting strength applied.

As a result of statistical analysis; the bursting strength on yarn linear density and fabric density were determined to be effective, but the fabric structure was determined to be ineffective. As seen in *Figure 3*, it was observed that the washing process reduces the durability and bursting strength of knitted fabric.

In the figure, bursting strength values before and after the washing cycles are compared, where a decrease in the bursting strength is observed after washing.

Air permeability

Air permeability tests were made for a test pressure drop of 100 kPa (20 cm² test area) in accordance with 9237 using an SDL Atlas air permeability tester. The measurements were repeated ten times for each fabric.

Air permeability is the ability to pass air through fibres, yarns and fabric structure. The air permeability results have been given in *Figure 4*, where the values of the fabrics have been analysed. *Figure 4* shows that the air permeability also tends to increase with an increase of the stitch length, as expected. As the stitch length increases, the compactness of the fabrics decreases due to the decrease in the number of stitches. The fabrics' structural parameters and air permeability performance were investigated and some models developed by different researchers to predict the permeability of fabrics are explained. When analysed statistically, yarn linear density and fabric density are determined to have a significant effect on air permeability.

As can be seen from *Figure 4*, where air permeability values before and after washing cycles are compared, a decrease in air permeability was observed after washing.

It was thought that after the washing the fabric was pulled and its pores reduced, thereby reducing the air permeability of the knitted fabrics.

Dimensional stability

The dimensional stability of fabric specimens subjected to procedures typical of home laundering and drying practices was measured using pairs of bench marks applied to the fabric before laundering. The general procedures for preparing and marking out of samples are laid down in the ISO standards. Specimens

are prepared with 500 mm x 500 mm dimensions and marked with three sets of marks in each direction, a minimum of 350 mm apart and at least 50 mm from all edges. All samples are then conditioned in a standard atmosphere. After measurement the samples are subjected to the treatment and procedure for conditioning required, and measurements are repeated to obtain the final dimensions. A specified water level is used, and the water temperature selected for the washing cycle and rinsing is less than 40 °C (°F). Standard reference detergent is added for 66 ± 1 g. test specimens and enough ballast to make a $1.8 \pm 0,1$ kg ($4.00 \pm 0,25$ lb) load. Modal/combed cotton blend knitwear fabrics are subjected to ten laundering cycles in a variety of washing and drying conditions. The dimensional stability both widthwise and lengthwise are evaluated as growth (+) or shrinkage (-). The dimensional stability of sample knitted fabrics are given **Figures 5 and 6**.

Modal/combed cotton blended fabrics underwent washing and drying cycles ten times repeatedly. Changes in the widthwise direction of the lacoste fabrics were measured between 5-15%, and in lengthwise direction between 10-20%. Changes in the widthwise direction of the plain fabrics were measured between 5-25% and in the lengthwise direction between 5-10%. Besides this, for plain fabrics, 1-3% elongation in the lengthwise direction was determined. It was noted that dimensional change in a knitted fabric is determined by a number of factors, such as fibre characteristics, the stitch length, machine gauge, yarn twist, knitting tension, and washing and drying methods. However, the factors most responsible for dimensional changes are known to be the swelling of yarn and the relaxation of internal stress to which yarns are subjected during the knitting process.

Statistical significance analysis

The experimental results were statistically evaluated using Design Expert Analysis of Variance (ANOVA) software with F values at a significance level of $\alpha = 0.005$, with the intention of exploring whether there is any statistically significant difference between the variations obtained. We evaluated the results based on the F-ratio ($\text{prob} > F$). The lower the probability of the F-ratio, the stronger the contribution of the variation and the

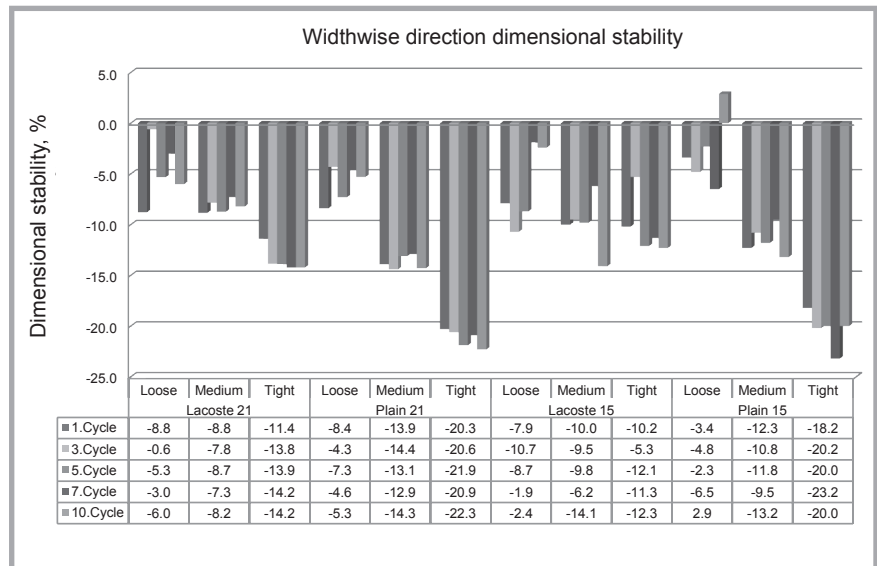


Figure 5. Effect of widthwise direction dimensional stability of modal/combed cotton blended fabrics.

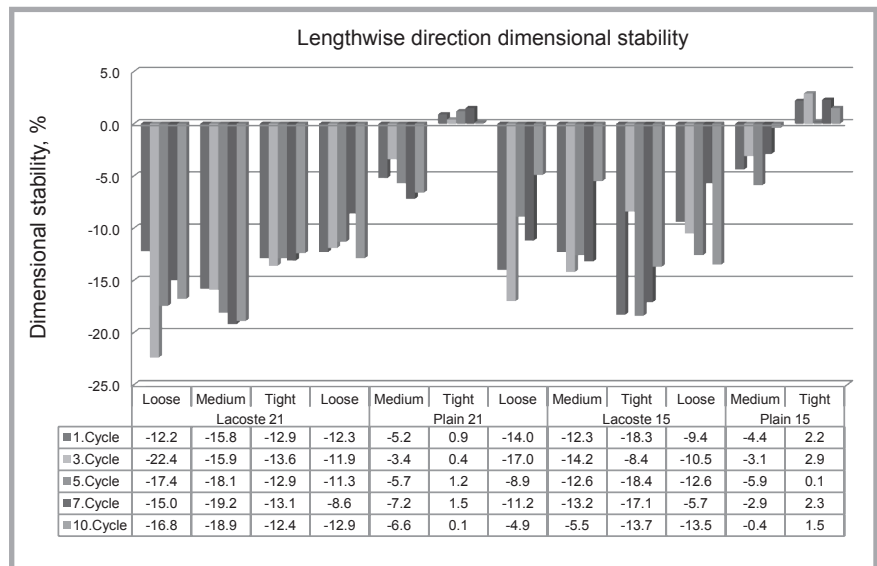


Figure 6. Effect of lengthwise direction dimensional stability of modal/combed cotton blended fabrics.

more significant the variable. **Table 4** summarises the statistical significance analysis for all the data obtained in the study, evaluated separately.

Three main factors were identified: the fabric structure (plain and lacoste), yarn linear density (tex 21 and 15) and fabric density (loose, medium, tight). In contrast. Yarn linear density as major factor has a great influence on the bursting strength, with an approximated contribution of 81-77%, air permeability – with an approximated contribution of 67-68%, and the fabric weight per unit area – with an approximated contribution of 71-63%.

Fabric structure becomes a minor factor, with a contribution of around 1-6%. Fabric density with a contributions of around 20-25% was found.

As a result of statistical analysis, yarn linear density and fabric density were found to have a significant effect on the bursting strength. The fabric structure, fabric density and yarn linear density have a significant influence on air permeability. But the most effective parameter is yarn linear density. It was also determined that fabric structure and fabric density are effective with respect to dimensional stability.

Table 4. Statistical significance analysis. Note: F-V is the F-Value. P-V is the P-Value and C % is the Contribution in percent.

Fabric properties		Fabric weight, g/m ²	Washing cycle after fabric weight, g/m ²	Fabric thickness, mm	Washing cycle after thickness, mm	Bursting strength, kPa	Washing cycle after bursting strength, kPa	Air permeability, dm ³ /m ² .s	Washing cycle after air permeability, dm ³ /m ² .s
Fabric structure	F-V	24.21	22.60	27.04	326.2	6.13	5.98	12.89	55.99
	P-V	0.0017	0.0021	0.0350	<0.0001	0.0425	0.0444	0.0089	0.0174
	C%	9.93	10.94	34.65	75.76	0.66	1.76	6.21	5.91
Yarn number	F-V	173.53	130.58	15.62	91.71	758.73	264.10	138.56	649.33
	P-V	<0.0001	<0.0001	0.0585	<0.0001	<0.0001	<0.0001	<0.0001	0.0015
	C%	71.21	63.20	20.01	21.30	81.45	77.50	66.74	68.5
Fabric density	F-V	19.47	23.21	5.21	2.83	79.86	31.84	24.58	105.94
	P-V	0.0014	0.0008	0.1610	0.1260	<0.0001	0.0003	0.0007	0.0094
	C%	15.98	22.47	13.35	1.31	17.15	18.69	23.68	22.35
Fabric structure x yarn number	F-V	9.81	13.95	6.58	15.43	0.21	39.26	0.84	1.87
	P-V	0.0886	0.0648	0.1242	0.0591	0.6901	0.0245	0.4565	0.3044
	C%	1.33	1.20	8.43	1.41	0.021	0.96	0.15	0.20
Fabric structure x fabric density	F-V	1.81	2.32	4.56	0.14	1.02	10.98	4.40	7.55
	P-V	0.3564	0.3011	0.1799	0.8750	0.4953	0.0835	0.1850	0.1170
	C%	0.49	0.40	11.68	0.026	0.20	0.54	1.55	1.59
Yarn number x fabric density	F-V	2.88	9.47	3.63	0.048	1.65	10.25	3.78	5.91
	P-V	0.2576	0.0955	0.2158	0.9545	0.3777	0.0889	0.2092	0.1448
	C%	0.78	1.62	9.31	8.7	0.33	0.50	1.33	1.25
Fabric structure x yarn number x fabric density	C%	0.27	0.17	2.56	0.18	0.20	0.049	0.35	0.21
		R ² 0.9713	R ² 0.9661	R ² 0.9744	R ² 0.9837	R ² 0.9925	R ² 0.9795	R ² 0.9663	R ² 0.9675

Table 5. Statistical significance analysis dimensional stability.

Fabric properties		F-V	P-V	C%
Fabric structure	Widthwise direction	66.44	<0.0001	10.22
	Lengthwise direction	170.86	<0.0001	51.24
Yarn number	Widthwise direction	4.90	0.0366	0.75
	Lengthwise direction	9.81	0.0041	2.94
Fabric density	Widthwise direction	199.76	<0.0001	61.48
	Lengthwise direction	22.89	<0.0001	13.73
Number of laundering cycle	Widthwise direction	0.96	0.4452	0.59
	Lengthwise direction	0.53	0.7182	0.63
Fabric structure x fabric density	Widthwise direction	38.95	<0.0001	11.99
	Lengthwise direction	23.79	<0.0001	14.27
Yarn number x fabric density	Widthwise direction	1.39	0.2681	0.43
	Lengthwise direction	4.05	0.0290	2.43
Fabric density x number of laundering	Widthwise direction	3.20	0.0128	3.94
	Lengthwise direction	1.29	0.2893	3.10
		R ² 0.8847	R ² 0.8617	

Conclusions

The main aim of this work was to investigate the effect of the principal washing and drying variables on the dimensional stability, fabric weight, fabric thickness, bursting strength and air permeability of knitted fabrics. In this study, parameters were investigated for a series of plain (single jersey), lacoste fabrics made from 50/50 modal/combed cotton blended ring spun yarns. Tests were performed according to ISO standards and changes in the dimensions were measured right after each cycle.

When the findings of this experimental study were evaluated, it was observed that dimensional stability, bursting strength and air permeability properties of the fabrics change statistically significantly with a change in the yarn linear density and fabric density.

Thickness values of the samples were very close to each other, and it was found that the differences between the thickness values were not statistically significant.

The investigations show that an increase in the stitch length of the fabric inves-

tigated increases its permeability to air, while with an increase in linear density, yarn permeability to air of the knits decreases. In addition it was estimated that the correlation between the tightness factor of the knit and its permeability to air is strong.

As far as the stitch length is concerned, it is observed that with an increase in the stitch length, the fabric weight and bursting strength values decrease, whereas the fabric thickness and air permeability values increase.

An inverse relationship between air permeability and bursting strength is clearly demonstrated. The tight structured plain (single jersey) knitted fabrics produced from yarn of 21 tex linear density had the highest bursting strength values, whereas the loose structured lacoste knitted fabrics produced from yarn of 15 tex linear density had the highest air permeability values.

Repeated laundering followed by flat drying helps the loops to approach their relaxed shape, which could be accepted as the minimum energy state. When the loops reach their fully relaxed shape, the fabric becomes more dimensionally stable, hence it has fewer tendencies to shrink.

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The conference will look at the supply & demand trends of feedstocks, the global and European polyolefin markets, as well as the main drivers amongst end-products. Building up on last year's feedback, the event will also take an in-depth look into trends & innovations, new technologies developments and predictions on the long to very long term. Over the two days, the participants will discuss topics such as lightweighting, recycling & upcycling of polyolefins, the PET trend, as well as bio-based PE & PP, through case studies and interactive discussions led by industry experts.

This new edition will bring together senior executive from petrochemical companies, plastic converter, technology providers, chemical intermediate suppliers, researchers, as well as other influential stakeholders from the value chain.

Join us in Dusseldorf to exchange your point of view with your peers and engage in excellent networking opportunities.

More information: <http://www.wplgroup.com/aci/event/polyolefins-conference/>