Impact of repetitive washing on recycled cotton knitted fabrics: a comprehensive physical property analysis

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ABSTRACT – REZUMAT

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The textile industry's rapid growth has significantly increased cotton textile production, escalating the volume of textile waste. Recycling cotton waste emerges as a solution, providing an opportunity to repurpose waste into valuable products. In this regard, the durability of recycled cotton fabrics under domestic laundering conditions becomes critical to ensuring sustainable textile practices. This research explored the effects of repetitive washing on the physical characteristics of knitted fabrics containing recycled cotton. The study focused on evaluating changes in key fabric properties, such as mass per unit area, thickness, density, air permeability, and fabric stretchability, including both elongation and unrecovered elongation, after subjecting the specimens to numerous washing cycles. Initial findings highlighted a significant increase in the mass per unit area during the first 10 washes, leading to a decrease in weight beyond the 10th washing cycle. This study further identified that changes in the dimensions of the fabric play a more critical role than the loss of fibres, contributing to the increased mass per unit area values. Results showed considerable variances in fabric attributes post-laundering, with notable adjustments in thickness, density, and air permeability. The study underscored a complex interaction between the washing conditions and fabric properties, where certain characteristics, specifically air permeability and the unrecovered elongation, were significantly affected.

Keywords: *recycled cotton, knitted fabrics, repetitive washing, domestic laundering, sustainability*

Impactul spălării repetitive asupra tricoturilor din bumbac reciclat: o analiză completă a proprietăților fizice

Dezvoltarea rapidă a industriei textile a dus la creșterea semnificativă a producției de textile din bumbac și, prin urmare, la creșterea volumului de deșeuri textile. Reciclarea deșeurilor din bumbac apare ca o soluție, oferind posibilitatea de a transforma deșeurile în produse valoroase. În acest sens, durabilitatea materialelor textile din bumbac reciclat în condiții de spălare internă devine esențială pentru asigurarea unor practici textile durabile. Această cercetare a explorat efectele spălării repetitive asupra caracteristicilor fizice ale tricoturilor care conțin bumbac reciclat. Studiul s-a concentrat pe evaluarea modificărilor proprietăților cheie ale materialului textil, cum ar fi masa pe unitatea de suprafață, grosimea, densitatea, permeabilitatea la aer și elasticitatea tricotului, inclusiv alungirea și alungirea nerecuperată, după supunerea probelor la numeroase cicluri de spălare. Constatările inițiale au evidențiat o creștere semnificativă a masei pe unitatea de suprafață în timpul primelor 10 spălări, care a condus ulterior la o scădere a greutății după cel de-al 10-lea ciclu de spălare. Acest studiu a identificat în continuare faptul că modificările dimensiunilor tricotului joacă un rol mai important decât pierderea fibrelor, contribuind la creșterea valorilor masei pe unitatea de suprafață. Rezultatele au arătat variații considerabile ale atributelor tricotului după spălare, cu ajustări notabile ale grosimii, densității și permeabilității la aer. Studiul a evidențiat o interacțiune complexă între condițiile de spălare și proprietățile tricotului, în care anumite caracteristici, în special permeabilitatea la aer și alungirea nerecuperată, au fost afectate semnificativ.

Cuvinte-cheie*: bumbac reciclat, tricoturi, spălare repetitivă, spălare domestică, sustenabilitate*

INTRODUCTION

Clothing, a fundamental human necessity, has been transformed into a disposable product due to today's consumer perception, increased diversity, easy access to more affordable products, business models, etc. Consequently, the rising demand generates millions of tons of textile waste annually. This waste predominantly ends up in landfills, is burned, or is shipped abroad, with only a minimal amount undergoing recycling [1]. Cotton is a vital material in the textile industry and accounts for a significant amount of textile waste because of its comfort qualities [2]. According to projections, by 2030, there will be 148 million tons of textile waste worldwide, of which 35–40% will come from cotton waste [3].

Recycled cotton, with its potential as a prime material for a sustainable industry, can yield a variety of valuable products despite its limitations arising from its natural origins and post-processing challenges like dyeing and blending [3]. Achieving efficient recycling methods for post-consumer waste cotton is crucial to producing consistently high-quality items, reducing waste generation, and mitigating the environmental impact of landfilling and incineration [4]. Additionally, examining the fabric's structure after prolonged use is essential to understand its enduring characteristics.

Textiles, made from diverse fibres and yarns, provide various end-use applications but are significantly influenced by environmental and mechanical factors, including use conditions and maintenance practices like ironing, laundering, and exposure to sunlight [5, 6]. Laundering, critical for maintaining a garment's performance and appearance over time, subjects textiles to tough conditions such as wetting, agitation, heat, chemicals, and pressing. This repeated process alters the physical properties of textiles, leading to deformations, with knitted fabrics particularly susceptible to stretching and mechanical damage that often doesn't fully reverse, highlighting the challenges of everyday use and laundering [5].

Customers expect textiles to retain their shape, size, and performance close to new products after multiple washing cycles, with a growing demand for high-quality fabrics that maintain superior performance through numerous laundering sessions [6, 7]. This expectation is particularly challenging for knitted fabrics, which exhibit more dimensional changes and physical deformations after repeated washes compared to woven materials [8]. Therefore, it is crucial to investigate the performance changes in the tactile, mechanical, comfort, and surface properties of textiles made from recycled fibres due to the effects of repeated washing. This area attracts the attention of researchers aiming to evaluate the long-term performance of garments subjected to repetitive washing.

Studies systematically investigate the impact of principal washing and drying variables on dimensional stability and distortion of knitted fabrics [5]. The determination of the number of laundering cycles needed for knit fabrics to achieve stability, along with the effect of wash water temperature, is thoroughly examined [9], as well as the contribution of fabric characteristics and laundering to the shrinkage of weft knitted fabrics [10]. Research also explores how repetitive washing affects the air permeability of cotton woven fabrics [11] and the comfort characteristics post-laundering [12]. Novotná et al. examined how washing and moisture affect the air-permeability of 100% cotton plain weave fabrics and the impact of different seam types and found that repeated washing significantly impacts air-permeability in both dry and wet states [11]. Midha et al. evaluated air permeability, moisture vapour permeability, moisture management, and drying rate of denim fabrics with cotton, polyester, and lycra cotton weft yarns and the effects of enzyme washing and repeated laundering on these properties [12]. Optimal laundering conditions for minimising shrinkage in cellulose-based fabrics have been explored by Chung and Kim [13]. Studies on the effects of laundering on the dynamic elastic behaviour of fabrics conclude that laundering cycles do not influence the dynamic work recovery (DWR) and stress values of these fabrics [14]. Another research investigated how repeated laundering and dry-cleaning affect the comfort properties of meta-aramid fabrics, finding increased thickness, areal density, thermal resistance, and water vapour resistance but decreased air permeability due to fabric shrinkage and swelling [15]. The impact of washing cycles on the cyclic deformation of elastane-knitted fabrics was investigated. The effect of repeated washing cycles on the residual extension of the fabrics is gradual. It is seen that the fabrics of higher settings show lower residual extension for all washing cycles. The critical washing cycles in this research seem to be 5 and 15 for all test fabrics in the two different test directions [8]. The influence of recycled fibre content and selected variables on fabric performance pre and post-laundering [16] and the impact of laundering variables on microfiber release [17] have been comprehensively analysed. Another study assessed the effects of washing temperature and time on garment colour loss, colour transfer, and microfiber release using retail consumer clothing. Findings suggest that reducing laundry time and temperature could significantly extend garment longevity and reduce dye and microfiber release into the environment while also saving energy [18].

Considering the literature review, there is a research gap in assessing the physical performance of fabrics containing recycled cotton after multiple washing cycles. This study aimed to fill the gap by examining the impact of repetitive washing on the physical characteristics of knitted fabrics containing recycled cotton. The properties examined within the scope of this research were chosen due to their critical impact on the performance and longevity of textiles in daily use. The changes in critical fabric properties, including mass per unit area, fabric thickness, fabric density, air permeability, and stretchability, which include both elongation and unrecovered elongation, were evaluated following specified washing cycles. This study distinguishes itself by specifically examining the impact of repetitive washing on the physical properties of recycled cotton knitted fabrics, an area less explored in existing literature.

METHODOLOGY

Material

In the context of this study, four different single jersey fabrics with varying ratios of recycled cotton content have been selected. Different yarn counts were chosen to examine the impact of yarn variety on fabric properties post-laundering. The fabric compositions, yarn counts and mass per unit area values of the fabrics that constitute the material of the study are given in table 1. The fabrics were subjected to the same

Table 1

THE CHARACTERISTICS OF FABRICS EVALUATED

Fabric code	Fabric composition	Yarn count	Mass per unit area (g/m^2)
F1	100% R-Co	20/1 Ne	188.30
F2	60% Co, 40% R-Co	48/1 Ne	196.30
F3	75% Co, 25% R-Co	30/1 Ne	187.25
F4	80% Co, 20% R-Co	24/1 Ne	201.80

finishing processes: silicone finishing, thermofixing, and sanforisation.

Repetitive washing process

In the study, washing cycles were conducted in sets of 10 repetitions. After every 10 washing cycles, a sample piece was taken out of the wascator, and the washing process continued for the remaining samples until reaching 30 washes. As a result, fabric samples subjected to 10, 20, and 30 repeated washings were obtained. The "ISO 6330:2022 – Textile tests – Washing and drying procedures with a household washing machine" standard was used for the washing processes. The repeated washing processes conducted in the James Hill Wascator FOM71MP washing machine opted for the 4N program simulating daily use (water temperature 40 °C, spin speed 1200 rpm, and washing time of 28 minutes). Reference 3 detergent, as specified in the standard, was added to the washing process in 20 g measurements. After the washing cycles, the samples were laid out on a flat surface (Procedure C) to dry. As stated in the standard for the washing process, Type 1–100% cotton supplementary fabrics were washed together with the test samples to achieve a weight of 2000 g.

As a result of the repetitive washing procedure, in total, 16 samples were obtained, unwashed, and after 10, 20, and 30 washing cycles.

Physical evaluation

The weights of the fabrics (g/m^2) were obtained according to the "TS 251:2019 – Determination of Mass Per Unit Length and Mass Per Unit Area of Woven Fabrics" standard. Afterwards, the weight change was calculated using equation 1 [16] to demonstrate the difference that occurred during washing cycles:

$$\textit{Weight change}\ (\%) = \frac{W_0 - W_x}{W_0} \times 100 \qquad (1)$$

Where W_0 is the initial weight; W_x – weight value after related washing cycle.

In the fabric thickness analysis, the SDL ATLAS M034A model fabric thickness device was used, and tests were performed according to the "ISO 5084: 1996 – Textiles. Determination of thickness of textiles and textile products" standard. The measurements, of course, and wale numbers for fabrics were determined in accordance with the "EN 14971:2006 – Textiles. Knitted fabrics. Determination of the number of stitches per unit of length and unit area". Moreover, the air permeability test was conducted according to the "ISO 9237:1995 – Textiles. Determination of the permeability of fabrics to air" standard on an FX 3300 Air Permeability Tester device, with samples having a measurement area of 5 cm^2 and under a pressure of 100 Pascal. To measure the elasticity of fabrics, the tests were conducted according to the "ISO 20932-1: 2018 – Textiles – Determination of the elasticity of fabrics – Part 1: Strip tests" standard and the elongation values were obtained as percentages in both course and wale direction. The unrecovered elongation tests were performed using the samples of fabric elongation tests. A 50 mm distance was marked on the samples as the initial reference distance before performing the measurement. After the tests, the samples were left for 30 minutes to recover. The distance between the reference marks was then measured, taking the previously determined 50 mm length marks. The unrecovered elongation values were calculated using equation 2 [19]:

$$\textit{Unrecovered elongation}\ (\%) = \frac{Q - P}{P} \times 100 \qquad (2)$$

where C is the unrecovered elongation; P – initial 5 mm reference distance; Q – the subsequent distance between reference marks.

Statistical evaluations were conducted utilising IBM SPSS 20 software. To determine the effects of the washing cycles and fabric types on the examined parameters, namely air permeability, fabric elongation, and unrecovered elongation, independent t-tests were used, while a one-way ANOVA test was utilised to observe the effects of the number of repetitions in repeated washing processes. This independent t-test is used to determine if there is statistical evidence that the means of two independent groups are significantly different, whereas the one-way ANOVA test allows one to determine whether there are any statistically significant differences between the means of three or more independent groups. To investigate both the interaction and individual impacts of each parameter, Univariate tests were utilised. Additionally, to ascertain the significant differences between group means, post-hoc analyses were carried out employing the Duncan test. The Duncan test was utilised in this study to identify statistically significant differences between group means after conducting an ANOVA. All test outcomes were considered at a significance level of 0.05.

RESULTS AND DISCUSSION

In table 2, the mass per unit area and thickness values obtained for the sample fabrics based on the washing procedure were provided.

The change in the weights of fabrics due to washing cycles was calculated in two different ways using equation 1. Figure 1 is a graphical representation of the obtained data. The data given in the graph on the left calculates the change in weight values obtained after every 10 washing cycles based on the unwashed weight value of the fabric. The graph on the right, on the other hand, is derived by calculating the percentage change between the values obtained after every 10 washes to more easily observe the sequential change resulting from the washing cycles. The observation of negative weight loss values in figure 1 indicates an increase in the fabric weights compared to their initial values. Research in the literature showed that varying results were obtained regarding

Table 2

THE WEIGHT AND THICKNESS VALUES OF THE SAMPLES OBTAINED AFTER WASHING CYCLES					
Fabrics	**Washing cycles**	**Mass per unit area (g/m²)**		**Fabric thickness (mm)**	
		Mean	**Std. deviation**	**Mean**	**Std. deviation**
F1	Unwashed	188.30	6.263	0.204	0.002
	10 cycles	225.30	3.564	0.201	0.006
	20 cycles	217.95	1.095	0.171	0.002
	30 cycles	217.65	2.759	0.226	0.004
F2	Unwashed	196.30	4.052	0.230	0.003
	10 cycles	212.90	8.253	0.231	0.002
	20 cycles	223.80	3.990	0.191	0.003
	30 cycles	206.05	10.872	0.244	0.006
F3	Unwashed	187.25	2.733	0.231	0.002
	10 cycles	201.90	5.064	0.232	0.003
	20 cycles	195.95	4.648	0.196	0.004
	30 cycles	192.65	4.343	0.258	0.003
F4	Unwashed	201.80	3.488	0.236	0.001
	10 cycles	218.45	7.214	0.239	0.005
	20 cycles	218.15	2.993	0.189	0.002
	30 cycles	208.85	8.077	0.253	0.004

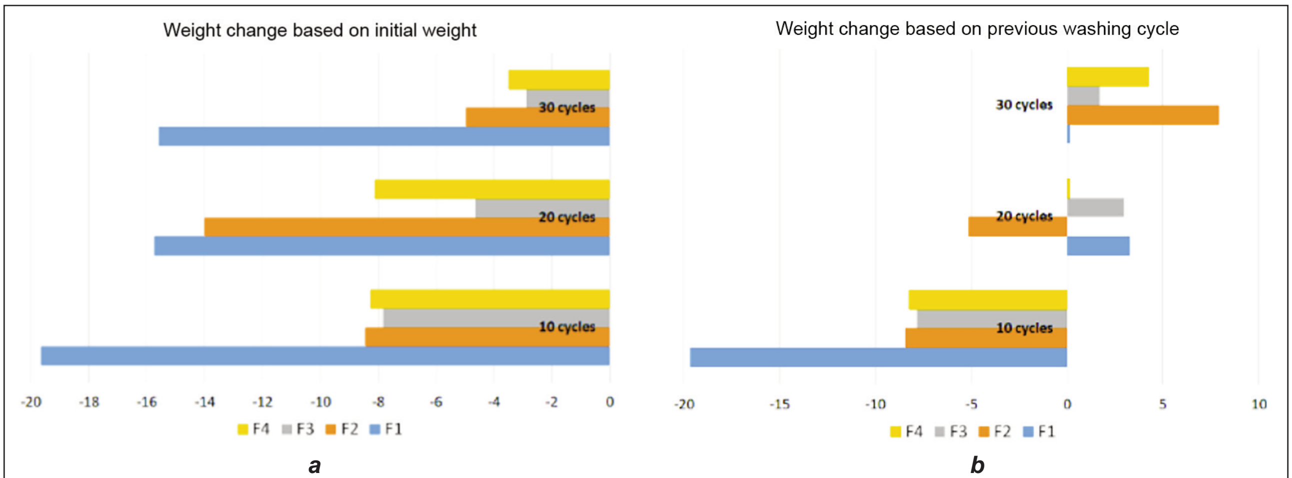

Fig. 1. The change in weight based on: *a* – the initial fabric weight; *b* – weight obtained in the previous washing cycle

this topic. Yılmaz and Keleş observed a decrease in weight change after repetitive washing in single jersey fabrics containing 50% recycled cotton and 50% PES [16]. On the contrary, Rauf et al. found a negative weight change in 100% cotton Single Jersey T-shirts, supporting the results obtained in the presented study [20]. In their 2017 study, Hernandez et al. examined microplastic waste resulting from domestic washing cycles and found that the fibre lengths in the wastewater ranged from 100 to 800 µm [21]. Although microplastics were the focus of their study, it is also evident in our study that the proportion of short fibres increases due to the recycling process of recycled cotton fibres. This increase in short fibres contributes to weight loss during the washing cycle. Statistical evaluation results also support this fact. Both the type of fabric ($p = 0.00$) and the number of washing cycles ($p = 0.00$) had statistically significant impacts on the weight of the fabric. Similarly, both fabric type ($p = 0.00$) and washing cycles ($p = 0.00$) significantly affected the fabric thickness.

In figure 1, *b*, a significant weight increase is observed in the first 10 washing cycles, with the general trend after the 10th wash being a decrease in weight. Particularly in fabrics containing recycled cotton, due to the short lengths of these fibres, a loss of weight due to fibre loss from mechanical effects during washing is expected. However, factors such as the knit type, density, yarn number, etc., especially in single jersey fabrics, significantly affect the dimensional stability. In this study, it was observed that dimensional change had a more significant effect than fibre loss, increasing the mass per unit area values.

Table 3

THE DENSITY VALUES OF SAMPLE FABRICS AS A RESULT OF WASHING CYCLES								
Fabrics / Washing cycles	F1		F2		F3		F4	
	Wale	Course	Wale	Course	Wale	Course	Wale	Course
Unwashed	12	16	16	20	16	21	14	18
10 cycles	13	17	17	21	17	21	15	19
20 cycles	12	16	15	20	16	20	14	19
30 cycles	12	16	15	20	15	20	14	18

Fabric density

The changes in the density values of the fabrics due to the washing procedure are presented in table 3. The densities of fabrics with a single jersey knit structure tend to increase up to an average of 20 washes and then decrease. Supporting these findings, Sülar and Oner indicated in their study that the critical washing cycles were determined to be 5 and 15 across all test directions [8]. It was observed that the density values of the sample fabrics used in the study also show a similar trend. The F1 fabric, which is produced from thicker yarns and contains 100% R-Co, did not show a significant change in density values due to the washing procedure compared to other samples. In line with the given literature, an increase in the row value was only observed after the 10th wash.

In addition, Anand et al. conducted cyclic washing tests using plain weaved fabric and reported that the maximum shrinkage occurred after the first washing cycle, with no significant changes observed in dimensional stability in subsequent washes [5]. The results of the present research showed a similar trend with literature, as fabric density values showed an increase after the 10th washing cycle. Regarding statistical evaluations, both fabric type ($p = 0.00$) and washing cycles ($p = 0.00$) had statistically significant effects on fabric density in both the wale and course directions.

Air permeability

Figure 2 presents a graphical representation of the air permeability values of sample fabrics after washing cycles. Upon examining the changes in fabrics due to washing cycles, it has been observed that up to the 20th wash, the fabrics' density values (table 3) increased, resulting in a decrease in air permeability values compared to the initial condition.

To determine the effect of the washing process on the air permeability values of fabrics containing recycled cotton, the air permeability values of unwashed and washed fabrics were compared, and according to the results of the independent t-test conducted, it has been determined that the washing process affects air permeability (t-value = 2.698; $p = 0.05$). The literature supports these findings as well. Chen-Yu et al. found that repetitive washing significantly reduces the air permeability of cotton specimens [22].

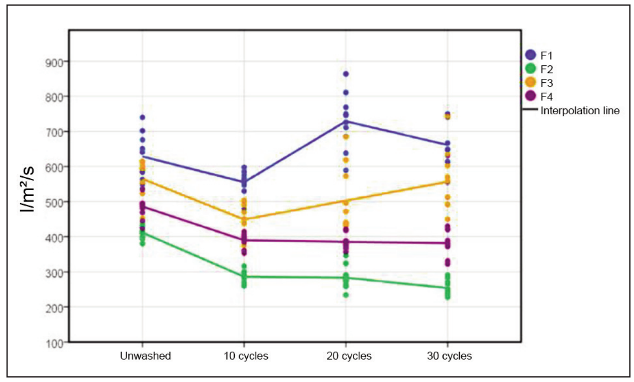

Fig. 2. Scatter diagram related to the air permeability values of fabrics considering washing cycles

Afterwards, the univariate analysis was performed to determine the impact of fabric type and washing cycles, as well as their interaction, on air permeability values. As indicated in table 4, both fabric type ($p = 0.00$) and washing cycles ($p = 0.00$) demonstrated statistically significant effects. Moreover, the interaction of these factors also exhibited a significant influence, which could potentially be due to the dominant characteristics of each parameter.

Table 4

THE UNIVARIATE ANALYSIS RESULTS FOR AIR PERMEABILITY			
Source	F	Sig.	Observed power
Fabric type	312.919	0.00	1
Washing cycle	26.956	0.00	1
Fabric type * Washing cycle	10.617	0.00	1

The results obtained by the Duncan tests are presented in table 5. Considering the effect of washing cycles on air permeability values, three subsets occurred. As stated above, during the washing cycles, shrinkage of the fabric structure was observed up to 20 washes, and as a result, the lowest air permeability values were obtained after the 10th wash, forming subset 1. The air permeability values for 20 and 30 washes, forming subset 2, showed less permeability compared to the unwashed fabrics' air permeability values. This situation is thought to be

Table 5

DUNCAN TEST RESULTS FOR AIR PERMEABILITY				
Washing cycles	**N**	**Subsets (α = 0.05)**		
		1	**2**	**3**
10 cycles	40	420.08		
30 cycles	40		463.43	
20 cycles	40		475.08	
Unwashed	40			522.75
	Sig.	1.000	0.313	1.000

not only due to the observed effect on the fabric structure but also possibly due to the use of recycled cotton, which increases the proportion of short fibres in the yarn and the ends of these fibres that block air passage.

Fabric elongation and unrecovered elongation

In figure 3, the dual axis graphs show the values of fabric elongation and unrecovered elongation values of each fabric for both course and wale directions.

Upon examining the fabric elasticity values obtained after repetitive washing tests, a significant increase in the fabric elongation values of the fabric samples was observed after the first 10 washes. This situation, as indicated by Sülar and Oner, suggests that the increase in fabric shrinkage values during the first 10 washing cycles leads to an increase in fabric elasticity [8]. However, after the 20th washing cycle, a decrease in fabric elasticity values was observed due to the release observed in the fabrics. Regarding unrecovered elongation values, the fabrics coded F1 and F4, having higher fabric thickness, displayed a different trend in permanent elongation values compared to the fabrics coded F2 and F3. Senthilkumar and Anbumani found that the laundering effect does not influence the recovery of cotton/spandex knitted fabrics [14]. In our study, however, the fabrics did not contain elastane, leading to unrecovered elongation due to repetitive washing. This indicates that the presence of elastane reduces the effect of permanent elongation.

The difference in elasticity and unrecovered elongation values between fabrics subjected to repetitive washings and unwashed fabrics was evaluated using the Independent samples t-test. According to the results obtained, it was determined that washing affected the elasticity properties in both directions (course: $p = 0.00$; wale: $p = 0.00$). It was found that the effect of the washing process on unrecovered elongation values was only in the wale direction of the fabric ($p = 0.00$), while it had no effect in the course direction ($p = 0.270$).

The results of the univariate analysis are presented in table 6. Upon examining the results, it was determined that the washing cycles had no statistically significant effect on the unrecovered elongation values measured along the course of the fabrics ($p = 0.38$). Similarly, it was observed that the interaction between fabric type and washing cycle also had an insignificant impact.

Table 7 represents the values obtained from the Duncan tests applied to the fabric elongation data. It was observed that three subsets have formed in the direction of the courses and four subsets in the direction of the wales. The repetitive washing's effect of increasing density on single jersey fabrics has resulted in higher fabric elasticity in both the course and wale directions compared to unwashed samples. Upon examining table 7, it is noted that the unwashed samples form subset 1 in both directions.

In table 8, the results of the Duncan test applied to the unrecovered elongation data are presented. It was observed that in the course direction, two subsets were formed, while in the wale direction, three subsets were formed. This situation was also observed in the results of the post-hoc tests conducted to determine the effect of each washing cycle on

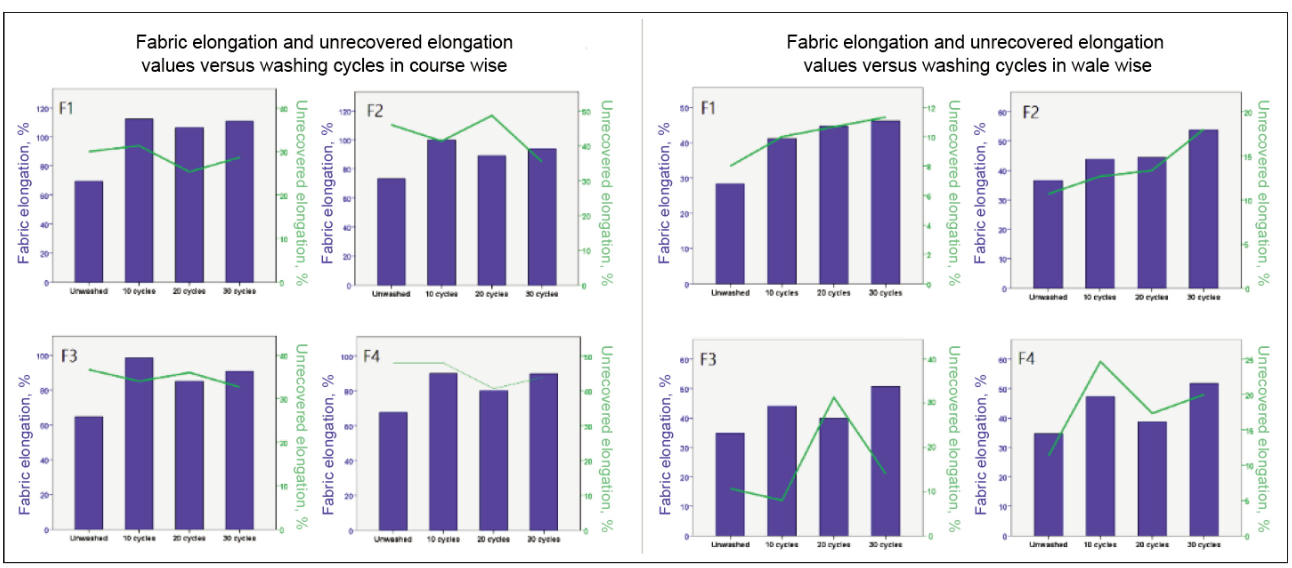

Fig. 3. Fabric and unrecovered elongation values versus washing cycles in course and wale-wise

Table 6

THE UNIVARIATE ANALYSIS RESULTS FOR FABRIC ELONGATION AND UNRECOVERED ELONGATION					
Elongation		**Source**	**F**	**Sig.**	**Observed power**
Fabric elongation	Course wise	Fabric type	55.547	0.00	1
		Washing cycle	178.788	0.00	1
		Fabric type * Washing cycle	5.903	0.00	0.999
	Wale wise	Fabric type	9.376	0.00	0.993
		Washing cycle	125.420	0.00	1
		Fabric type * Washing cycle	5.329	0.00	0.997
Unrecovered elongation	Course wise	Fabric type	40.299	0.00	1
		Washing cycle	3.164	0.38	0.678
		Fabric type * Washing cycle	2.333	0.38	0.822
	Wale wise	Fabric type	17.157	0.00	1
		Washing cycle	15.597	0.00	1
		Fabric type * Washing cycle	12.143	0.00	1

Table 7

DUNCAN TEST RESULTS FOR FABRIC ELONGATION											
Course wise						**Wale wise**					
Washing cycles	**N**	**Subsets (α = 0.05)**				**Washing cycles**	**N**	**Subsets (α = 0.05)**			
		1	**2**	**3**	**4**			**1**	**2**	**3**	**4**
30 cycles	12	68.766			-	30 cycles	12	33.623			
20 cycles	12		90.144		-	20 cycles	12		41.942		
10 cycles	12			96.436	-	10 cycles	12			44.105	
Unwashed	12			100.233	-	Unwashed	12				50.630
	Sig.	1.000	1.000	0.070	-		Sig.	1.000	1.000	1.000	1.000

the elasticity values of the fabrics in the course and wale directions. The differences in elasticity values in the course direction among the fabrics were generally found to be insignificant, with the only significant difference found between the unwashed samples and those subjected to 30 cycles ($p = 0.026$). In the wale direction, however, the differences between washing cycles were significant, with the difference between 10 cycles and 30 cycles ($p = 0.367$) and between 20 cycles and 30 cycles ($p = 0.239$) found to be insignificant.

CONCLUSIONS

The study was performed to evaluate the impact of repetitive washing on recycled cotton fabrics, highlighting the durability of these materials. The study highlights the significant impact of repetitive washing on various physical properties of recycled cotton knitted fabrics. Key findings include changes in mass per unit area, thickness, fabric density, and air permeability. The study underscores the complex interaction between washing conditions and fabric properties, emphasising the importance of understanding

Table 8

DUNCAN TEST RESULTS FOR UNRECOVERED ELONGATION									
Course wise					**Wale wise**				
Washing cycles	**N**	**Subsets (α = 0.05)**			**Washing cycles**	**N**	**Subsets (α = 0.05)**		
		1	**2**	**3**			**1**	**2**	**3**
30 cycles	12	35.167		-	30 cycles	12	10.167		
20 cycles	12	37.667	37.667	-	20 cycles	12		13.833	
10 cycles	12	38.667	38.667	-	10 cycles	12		15.833	15.833
Unwashed	12		40.1667	-	Unwashed	12			18.167
	Sig.	0.055	0.167	-		Sig.	1.000	0.109	0.063

these dynamics for the development of sustainable textile products.

Despite challenges from varied washing cycles and the origin of recycled cotton, the investigated fabrics demonstrated certain alterations observed in air permeability and unrecovered elongation. Considering the repetitive washing post-laundering, the fabrics display significant variations in key attributes, including thickness, density, and air permeability. The mass per unit area values during the initial 10 wash cycles were increased, which then transitioned to a reduction in weight after the 10th cycle. The research points out that dimensional changes in the fabric are more influential than fibre loss in contributing to the initial increase in mass per unit area. The study also utilised different yarn counts to examine the impact of yarn variety on fabric properties post-laundering. The findings indicate that yarn composition significantly affects the durability and performance of recycled cotton knitted fabrics under repetitive washing conditions.

Factors such as the type of fabric softener, the detergent used, the type and technology of the washing machine, the ratio of load capacity utilised, and the composition of the water significantly influence the characteristics of fabrics after laundering. The characteristics examined in this study were selected due to their critical impact on the performance and longevity of textiles in daily use. Other properties, such as tactile comfort, were not included due to the scope and limitations of the available data. Future research should focus on determining the more comprehensive comfort and mechanical performance characteristics of fabrics containing recycled cotton. Ultimately, this research contributes valuable insights into the sustainable development of the textile industry, promoting the efficient use of recycled materials and encouraging practices that extend the lifespan of textile products.

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