Proof-of-concept evaluation of textile waste upcycling through patchwork bedspread design

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ABSTRACT – REZUMAT

Proof-of-concept evaluation of textile waste upcycling through patchwork bedspread design

This pilot study investigates the performance characteristics of bedspreads produced through an upcycling-oriented design approach using the patchwork technique, compared to conventionally manufactured counterparts. Textile waste materials sourced from Zorluteks Tekstil Sanayi ve Ticaret A.Ş., certified by OEKO-TEX® STANDARD 100 and OEKO-TEX® STeP, were reprocessed into single-bed-sized bedspreads in accordance with sustainable design principles. Both upcycled and conventional bedspreads were composed of three layers, including regenerated fibre filling and 100% cotton woven fabric. Comprehensive testing was conducted to assess washing fastness, perspiration fastness (acidic and alkaline), rubbing fastness, water fastness, dimensional stability, tensile strength, and seam slippage tests in accordance with ISO standards. Exploratory statistical analysis indicated no clear differences in most fastness properties, except for alkaline perspiration fastness, where patchwork samples showed slightly reduced performance due to fabric heterogeneity. Notably, upcycled samples demonstrated higher tensile strength, attributed to increased stitching density, but exhibited greater seam slippage, likely due to multi-fabric assembly. These findings suggest that upcycled textile products, when manufactured using optimised methods, can match or exceed the mechanical and functional performance of conventional products, positioning upcycling as a viable industrial strategy for sustainable textile production.

Keywords: *upcycling, bedspread, patchwork, textile waste, sustainability*

Evaluarea practică a reciclării deșeurilor textile prin proiectarea de cuverturi de pat realizate prin tehnica patchwork

Acest studiu pilot investighează caracteristicile de performanță ale cuverturilor de pat produse printr-o abordare de design orientată spre reciclare, utilizând tehnica patchwork, în comparație cu cele fabricate în mod convențional. Deșeurile textile provenite de la Zorluteks Tekstil Sanayi ve Ticaret A.Ş., certificate de OEKO-TEX® STANDARD 100 și OEKO-TEX® STeP, au fost reprocesate în cuverturi de pat de dimensiuni pentru o persoană, în conformitate cu principiile de design durabil. Atât cuverturile reciclate, cât și cele convenționale erau compuse din trei straturi, inclusiv umplutură din fibre regenerate și țesătură 100% bumbac. Au fost efectuate teste cuprinzătoare pentru a evalua rezistența la spălare, rezistența la transpirație (acidă și alcalină), rezistența la frecare, rezistența la apă, stabilitatea dimensională, rezistența la tracțiune și testele de alunecare a îmbinărilor, în conformitate cu standardele ISO. Analiza statistică exploratorie nu a indicat diferențe clare în majoritatea proprietăților de rezistență, cu excepția rezistenței la transpirație alcalină, unde probele peticite au prezentat o performanță ușor redusă din cauza eterogenității țesăturii. În mod remarcabil, probele reciclate au demonstrat o rezistență la tracțiune mai mare, atribuită densității crescute a îmbinărilor, dar au prezentat o alunecare mai mare a cusăturilor, probabil din cauza asamblării mai multor țesături. Aceste constatări sugerează că produsele textile reciclate, atunci când sunt fabricate folosind metode optimizate, pot egala sau depăși performanțele mecanice și funcționale ale produselor convenționale, poziționând reciclarea ca o strategie industrială viabilă pentru producția durabilă de textile.

Cuvinte-cheie*: reciclare, cuvertură de pat, tehnica patchwork, deșeuri textile, durabilitate*

INTRODUCTION

Sustainability consists of a multilayered structure including sustainable materials, water and energy consumption, circular economy and recycling, social sustainability, and ethical production. Natural ingredients and recycled materials have frequently been used in studies on sustainable materials. Shen et al., by assessing the carbon footprint of recycled PET (rPET) fibres, found that they had a 32% lower environmental impact compared to conventional polyester production. Additionally, cotton was identified as the least preferred option due to its high ecotoxicity effects, eutrophication, and water and land use [1]. Another study highlighted the environmental benefits of natural fibres as composite materials by conducting a comprehensive review. Biodegradable composites have been found to show significant potential for use in sustainable packaging [2]. Sandin et al. analysed the environmental impacts of recycled cotton and polyester using a comparative life cycle assessment (LCA) method. The study describes potential barriers to achieving environmental benefits by increasing the reuse and recycling of textiles [3].

Apart from these, many biologically based materials such as mycelium [4], spider silk [5], bacterial cellulose [6], pineapple fibres [7] are also used for sustainability purposes.
Sustainable resource management and circular economy approaches aim to minimise material waste in production and consumption systems and use natural resources more efficiently. In this context, recycling and upcycling stand out as two important methods of waste management. While both approaches aim to utilise waste, they differ in terms of method, output, and environmental impact. Recycling is the reintegration of waste materials into the production process by transforming them into raw materials through physical or chemical processes. The principle of sustainability is achieved through recycling practices for textile products obtained from different production sources, such as yarn production, weaving, knitting, and ready-made clothing, which can be used in many industries [8]. Upcycling is the reprocessing of waste or unused products in a way that increases their value and transforms them into new functional products. Unlike recycling, in this method, the recycled material is produced without altering the physical or chemical structure of the material, resulting in a new product with a higher value or quality than the original product [3]. Upcycling techniques are divided into many areas, including physical methods, deconstruction & reconstruction, patchwork, function-based repurposing, and modular upcycling. The upcycled product created with the patchwork technique is a unique product with higher value than the original and can be reused and recycled many times [9].
This study compared the performance characteristics of a bedspread produced using patchwork, a frequently used upcycling method for home textile waste, with a traditionally produced bedspread, and evaluated their potential uses. To this end, the production processes, fabric parameters, and tests for washing, perspiration (acid and alkali), rubbing, water, dimensional stability, tensile strength, and seam slippage were conducted on two different home textile products. The test results were statistically analysed. This study was carried out with a limited sample and is a conceptual pilot trial.

GENERAL INFORMATION

Upcycling is a type of recycling process that transforms low-value materials into higher-value products. Because many fashion apparel products contain non-biodegradable chemicals that can harm the environment after disposal, the recycling of waste textiles has gained importance [10]. In this regard, many physical, thermal, and chemical processes are performed. Thermochemical conversion processes are technologically and economically viable options for processing low-value carbonaceous raw materials [11]. Pyrolysis, the thermal decomposition of carbonaceous components in an oxygen-free environment, is the most common thermochemical method [12]. Composite grinding is frequently used in mechanical recycling. The ground materials can be used as fillers in short-fibre composites [13]. While these conversion methods generally focus on the repurposing of industrial waste, the upcycling approach is not limited to industrial waste. In the textile sector, upcycling applications shaped by creative and aesthetic concerns are also gaining increasing importance. Upcycling applications in textiles involve the dismantling of outdated clothing and transforming it into new design products, adding aesthetic and functional value through techniques such as patchwork. In this context, patchwork is considered not only a sustainable production method but also a form of artistic expression that preserves cultural heritage. Patchwork is the art of creating a new surface by combining small pieces of fabric. Patchwork is a part of popular art and a language that expresses the culture and traditions of each nation [14].

METHODOLOGY

Materials

The study used 100% cotton woven fabric and 100% regenerated fibre, supplied by Zorluteks Tekstil Sanayi ve Ticaret A.Ş., holding OEKO-TEX® STANDARD 100 and OEKO-TEX® STeP certifications. The bedspreads are composed of three layers. The surface, produced using a patchwork technique using 100% cotton fabric and waste materials, is combined with 100% cotton fabric and a layer of regenerated fibre is added in between. Similarly, the bedspread, which contains no waste materials, was also produced using the same materials.

Methods

In this study, unused waste fabrics at Zorluteks Tekstil Sanayi ve Ticaret A.Ş. were repurposed using the patchwork method to fit the dimensions of a single bedspread. Within the scope of the study, a single bedspread made of reinforced fabrics was produced in accordance with the design principles. During the production process, unused or torn bedspread fabrics were cut to specific sizes, brought together, and stitched together (figure 1). In the later stages, the bedspread was prepared as a two-layered bed cover using regenerated fibre material (figure 1, *a*) and cut to fit the single size. 100% cotton woven white fabric was preferred for the back part, figure 1, *b*, and piping was used to close the edges of the bedspread. In the final stage, before the three layers of the bedspread were joined, an overlock process was applied, and then the edges were closed with piping. Stitching was done to secure the three layers. All sewing operations were carried out using a JUKI-CP-180 lockstitch sewing machine and a JUKI MO-6814S, YUKI YK 500T 02 piping machine. With this method, waste fabrics were re-evaluated, and environmental sustainability goals were contributed to. Within the scope of the study, fabric parameters, washing fastness, perspiration fastness (acid and alkali), rubbing fastness, water fastness, dimensional

a *b* *c*

Fig. 1. Parts of the bedspread formed in 3 layers: *a* – regenerated fibre; *b* – outer patchwork surface; *c* – 100% cotton fabric

Table 1

TEST METHODS STANDARDS

Tests	Test methods
Washing fastness-staining	ISO105C06 60°C ECE + sodium perborat (50 ml)
Perspiration fastness	ISO105E04
Rubbing fastness	ISO105X12'
Water fastness	ISO105E01
pH value	ISO3071-2020
Fabric weight	ISO3801-NEXTTM20
Dimensional stability	ISO63302A 60°C Tumble Dry
Tensile strength	ISO13934-1(100 mm/sec).
Seam slippage	13936-1 seam opening 6 mm (50 mm /sec)

stability, tensile strength, and seam slippage tests were performed. The test standards for the measurements are given in the table 1.

RESULTS AND DISCUSSIONS

Production of bedspreads and the characteristic properties of fabrics

Within the scope of the study, Zorluteks Tekstil Sanayi ve Ticaret A.Ş. produced a three-layer bedspread, currently in mass production, and a bedspread made using a patchwork technique from scrap pieces from mass production. The bedspread (B), produced using a patchwork technique, was assembled from 17 different pieces and has the same fibre and backing as the mass-produced sample (A). The fabric parameters for both products are provided in table 2.

The data obtained in the study were analysed using the SPSS 25.0 statistical package program.

Descriptive statistics were used for the study using mean and standard deviation values. In this study, an independent samples t-test was used to compare the test results of two different fabric types. Normality analyses were conducted using the Kolmogorov-Smirnov test, skewness, and kurtosis values.

A significance level of $p<0.05$ was accepted in the analyses.

Washing fastness

As part of the study, colour fastness analysis was conducted. The results showed that both samples achieved values between 4 and (table 3). This result indicates a high level of colour fastness. The fact that sample code B demonstrated this performance demonstrates that the reassembled fabric pieces maintained their quality standards. It is known that upcycled products can achieve colour fastness values

Table 2

FABRIC PROPERTIES OF BEDSPREADS

Coding	Weight (g/m^2)	pH	Weft fabric count (thr/cm)	Warp fabric count (thr/cm)	View
A	487.7	6.2	50	80	
B	760.3	6.8	60	90	

like conventional products when processed using the correct techniques [10].

Table 3

COLOUR FASTNESS TO WASHING						
Coding	**Washing fastness-staining**					
	CA	**CO**	**PA**	**PET**	**PAN**	**WO**
A	4-5	4-5	4-5	4-5	4-5	4-5
B	4-5	4-5	4-5	4-5	4-5	4-5

Perspiration fastness

In the perspiration fastness measurements carried out within the scope of the study, a decrease of 4-5 points was observed in samples A and B in an acidic environment, while a decrease of 2-3 points was observed in sample B in an alkaline environment (tables 4 and 5). The decrease in sample B indicates the instability of patchwork pieces, especially those consisting of different colours and weaves, in the alkaline environment. This supports the assertion that the variety of fabrics used in upcycling can make a difference in chemical fastness [3].

Table 4

COLOR FASTNESS TO PERSPIRATION (PH:5.5 ACID)						
Coding	**Perspiration fastness-staining (PH:5.5 ACID)**					
	CA	**CO**	**PA**	**PET**	**PAN**	**WO**
A	4-5	4-5	4-5	4-5	4-5	4-5
B	4-5	4-5	4-5	4-5	4-5	4-5

Table 5

COLOR FASTNESS TO PERSPIRATION (PH:8 ALKALI)						
Coding	**Perspiration fastness-staining (PH:8 ALKALI)**					
	CA	**CO**	**PA**	**PET**	**PAN**	**WO**
A	4-5	4-5	4-5	4-5	4-5	4-5
B	4	2-3	4	4-5	4-5	4

Rubbing fastness

In the rub fastness tests, sample A scored 4-5, and sample B scored 4 (table 6). In this case, both products were at acceptable levels, but the difference in surface thread density due to the patchwork technique caused a slight decrease in sample B. Natural fibres like cotton are known to have high rub resistance [1]. In upcycled products, this resistance depends on the number of layers and stitch density.

Table 6

COLOR FASTNESS TO RUBBING		
Coding	**Rubbing fastness-staining**	
	Dry	**Wet**
A	4-5	4-5
B	4	4

Water fastness

This test is performed to determine the tendency of a textile material to dissolve and migrate into its surroundings when it encounters water. Water fastness measurements were in the 4-5 range for both samples. This indicates that both products were dyed and fixed using high-quality dyeing and fixing processes. The different fabric production techniques did not significantly affect water fastness.

Table 7

COLOR FASTNESS TO WATER						
Coding	**Water fastness-staining**					
	CA	**CO**	**PA**	**PET**	**PAN**	**WO**
A	4-5	4-5	4-5	4-5	4-5	4-5
B	4-5	4-5	4-5	4-5	4-5	4-5

Fastness data analysis

In this study, five different test results of fabrics A and B were compared using the independent samples t-test. In the Washing fastness-staining, Perspiration fastness-staining (ACID) and Water fastness-staining tests, the means of both fabric types were the same (4.50±0.52) and no observed difference between samples was found ($p>0.05$). While no clear difference was observed in the Rubbing fastness-staining test ($p=0.139$, exploratory analysis), fabric A exhibited lower performance than fabric B in the alkaline perspiration fastness test ($p=0.045$, exploratory analysis) (table 8). Fabric A (3.92±0.79) exhibited lower performance than fabric B (4.50±0.52) in alkaline perspiration fastness ($p=0.045$, exploratory analysis).

Table 8

COMPARISON OF FASTNESS TEST RESULTS OF BEDSPREADS					
Coding	**Washing fastness-staining**	**Perspiration fastness-staining-ACID**	**Perspiration fastness-staining-ALKALI**	**Water fastness-staining**	**Rubbing fastness-staining**
A	4.50±0.52	4.50±0.52	4.50±0.52	4.50±0.52	4.5±5.78
B	4.50±0.52	4.50±0.52	3.92±0.79	4.50±0.52	4.0±0.0
Variance Homogeneity	0.988	0.988	0.887	0.988	0.059
P-Value	1.000	1.000	0.045	1.000	0.139

Dimensional stability

Dimensional stability indicates the percentage of dimension change (shrinkage or elongation) in the warp and weft directions of the fabric after any treatment. Dimensional stability is directly related to the weave type and the amount of yarn used [15]. According to the results obtained, the shrinkage of sample B produced by upcycling is higher. This is a result of the multiple stitch lines and fabric tension differences in sample B. While the average of fabric A was –3.35±1.63, the average of fabric B was found to be –1.25±1.06. The homogeneity of variance was calculated as 0.799, and the p-value as 0.007. (exploratory analysis). This result shows that there is an observed difference between samples between the two groups in the Dimensional stability test results ($p<0.05$) (table 9 and figure 2).

Table 9

DIMENSIONAL STABILITY TO WASHING AND COMPARISON OF TENSILE STRENGTH TEST RESULTS	
Coding	**Seam dlippage**
A	–3.35±1.26
B	–1.25±0.82
Variance homogeneity	0.799
P-value	0.007

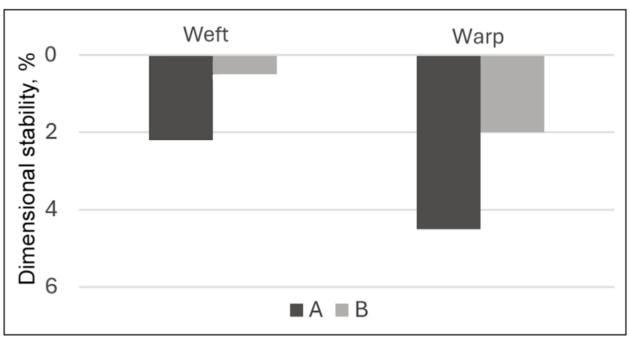

Fig. 2. Dimensional stability to washing and comparison of tensile strength test results

Tensile strength

Tensile strength analysis is a mechanical test performed to determine how long a fabric can withstand tensile forces applied in the warp and weft directions. The change in the rate of strength loss is determined by the material itself and any auxiliary materials that may affect it [16]. The higher tensile strength observed in the upcycled sample may partly stem from its higher fabric weight (760.3 g/m^2) and the presence of more sewing thread, not solely from the patchwork technique. The homogeneity of variance was calculated as 0.895, and the p-value was 0.014 (exploratory analysis). This result indicates an observed difference between samples in the Tensile strength test results between the two groups ($p<0.05$) (table 10 and figure 3).

Table 10

TENSILE STRENGTH OF BEDSPREADS AND COMPARISON OF TENSILE STRENGTH TEST RESULTS	
Coding	**Tensile strength (N)**
A	201.50±42.17
B	255.00±12.05
Variance homogeneity	0.895
P-value	0.014

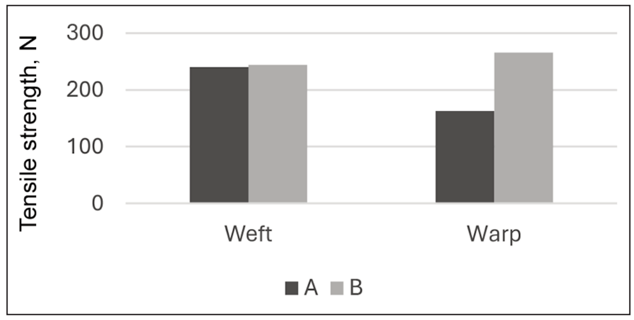

Fig. 3. Tensile strength of bedspreads and comparison of tensile strength test results

Seam slippage

The Seam Slippage is a mechanical test performed to measure the tendency of threads to separate from each other under tensile force in the seamed areas of a fabric. It is the most fundamental parameter determining the quality of the seam and the sewn fabric [17]. It tests whether threads unravel at the seams and the structural stability of the fabric in this area. Because the fabrics used in patchwork products have different properties and are made from multiple pieces, seam slippage increases. The seam slippage value for sample B is observed to be lower than that for sample A. This is due to the uneven tension distribution in the seam areas. When a seam is stretched by opening seam allowances on both sides relative to the seam line, an asymmetrical seam opening is observed. As the stitch density increases, the fabric is subjected to more stress in the seam areas. Due to the difference in material integrity and the high number of stitches, threads are more easily dislodged in some areas in the warp and weft directions in sample B, and seam slippage begins earlier (figure 4). In addition, high fabric weight is an important factor contributing to seam slippage [18–20]. The mean of fabric A was 198.25±19.14, while the mean of fabric B was 158.75±12.12. The homogeneity of variance was calculated as 0.609, and the p-value as 0.013. This result shows that there is an observed difference between the two groups in the Seam Slippage test results ($p<0.05$) (table 11).

Beyond mechanical and fastness properties, upcycling also carries significant environmental implications. Although this study did not conduct a full LCA, insights can be drawn from existing literature. Fatima et al. observed that converting PET bottle recycling into home textiles can significantly contribute to

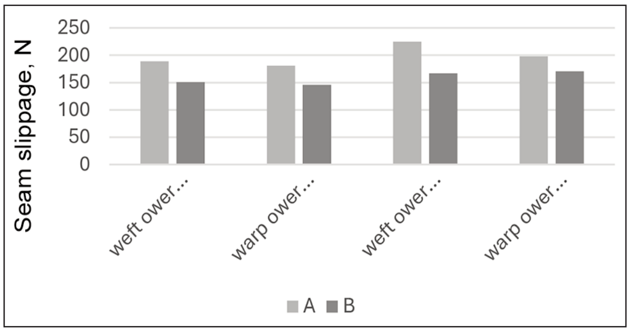

Fig. 4. Seam slippage of bedspreads

Table 11

COMPARISON OF TENSILE STRENGTH TEST RESULTS	
Coding	**Seam slippage (N)**
A	198.25±19.14
B	158.75±12.12
Variance homogeneity	0.609
P-value	0.013

material circularity while reducing environmental and economic burdens [21]. Similarly, Sandin and Peters demonstrated that textile reuse and upcycling may lead to substantial reductions in carbon emissions compared to conventional recycling or disposal pathways [3]. Incorporating a full LCA in future research would allow a quantitative comparison between upcycled patchwork products and conventionally manufactured bedspreads, thereby strengthening the environmental justification of upcycling strategies in home textiles.

Although these findings are promising, they represent preliminary insights due to the limited scope of this pilot study. Larger sample sizes, standardised fabric parameters, and additional replicates are required to validate and generalise these results.

CONCLUSIONS

The textile industry is one of the most environmentally intensive sectors in terms of water consumption, chemical use, and waste production. In recent years, interest in sustainable practices in the textile sector has rapidly increased in line with increased environmental awareness, circular economy principles, and sustainable development goals. In this context, sustainable textile production encompasses strategies focused on the use of environmentally friendly raw materials, water and energy-saving processes, the use of recycled materials, and extending product lifecycles.

This pilot study aims to explain the value and functionality of upcycling in bedspread production using the patchwork technique. It demonstrates that recycling textile waste using the patchwork technique not only preserves material value but can also improve certain mechanical properties, such as tensile strength, without compromising critical performance parameters such as washing and water fastness. While a slight decrease in alkaline perspiration fastness and higher seam slippage were observed in recycled products, these negative effects can be mitigated through optimised sewing techniques and fabric selection. A statistically significant design can produce products that meet industrial quality standards while reducing environmental impact. These findings are preliminary results of this study and are a guide for studies to be carried out with a larger sample. This pilot study is limited by the small number of specimens evaluated, as only two bedspread samples (one conventional and one upcycled) were tested. Larger sample sizes, standardised fabric parameters, and additional replicates are required to validate and generalise these results. Consequently, the observed differences should be interpreted as preliminary trends rather than definitive conclusions. This study is limited by the small number of tested samples and the variation in fabric weight and stitch density between the upcycled and conventional bedspreads. These factors may have influenced certain mechanical outcomes, particularly tensile strength and seam slippage. The findings, therefore, cannot be generalised to all upcycled or conventional bedspreads. To validate these initial observations, future studies should expand sample sizes, incorporate different textile waste compositions, and standardise material properties to better isolate the effects of upcycling techniques. These results highlight the potential of integrating recycling methodologies into large-scale textile production, thereby contributing to waste reduction, resource efficiency, and the promotion of sustainable improvements in tensile strength, and comparable results in colour fastness tests confirm that recycling-focused consumer products. Building on the preliminary findings of this pilot study, a wider range of textile waste types, including different fibres and blends, could use patchwork techniques in industrial contexts. Different usage and performance tests of these products can be applied, or consumer surveys can be conducted. Future research could explore LCA assessment of such products, assess their long-term durability, and develop standardised guidelines for industrial-scale recycling of home textiles.

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