

Article

Optimization Model for Tensile Strength Prediction in Woven Upholstery Fabrics Containing Recycled PP

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Abstract

The increasing environmental impact of the textile industry has led to the development of sustainable production methods. One of the effective approaches is the use of recycled fibers, which helps to save resources, reduce carbon emissions, and support the circular economy. This study investigates the feasibility of producing durable upholstery fabrics incorporating recycled polypropylene (r-PP) and virgin polypropylene (v-PP). Filament yarns with varying r-PP/v-PP blend ratios, produced by the melt spinning process, were used as weft yarns, while commercially available virgin polyester filament yarns were employed in the warp direction for all fabric samples. Performance tests in accordance with the standards were applied to the fabrics and the results were also evaluated statistically. The results show that acceptable performance is achieved in some mechanical properties if similar blend ratios and production parameters are used. In the study, an optimization model was developed to maximize the weft breaking strength using the equations obtained from the regression analyses. With the help of the mathematical model created, the values of other physical and performance properties of the fabric depending on the maximum breaking strength value could be estimated without the need for trial production. The model was solved using Lingo 18.0 optimization software. The solution of the model revealed that the optimum weft yarn blend ratio is 10/90 r-PP/v-PP, and the maximum weft breaking strength value is 562.45 N.

Keywords: recycled polypropylene; sustainability; upholstery fabric; optimization model; tensile strength

1. Introduction

Textile production has significant environmental impacts due to high water and chemical consumption and carbon emissions, driving the industry toward sustainable practices such as recycling. Recycling reduces the demand for virgin resources, lowers energy consumption, and mitigates environmental impact, while also supporting compliance with increasingly strict environmental regulations, particularly in the European Union. In the textile sector, recycling can be classified as closed-loop systems, in which post-consumer waste is reprocessed into similar products, and open-loop systems, where recycled materials are utilized in different applications to extend product life cycles [1].

Previous studies have largely focused on the recycling of polyester among synthetic fibers and cotton among natural fibers, whereas research on the recycling of polypropylene (PP) fibers remains limited. Nevertheless, PP is widely used in textiles such as upholstery fabrics, carpets, and technical textiles due to its low cost, ease of processing, high strength, low pilling tendency, and excellent chemical resistance [2]. Therefore, recycling



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polypropylene-based textile products is of particular importance for reducing textile waste, extending product life cycles, and enhancing sustainability.

Some studies in the literature have investigated the recycling of polypropylene and its reuse in textile applications, particularly focusing on fiber and yarn production as well as mechanical performance. Sözcü [3] recycled polypropylene yarn and carpet waste to produce r-PP yarns and evaluated their mechanical properties, demonstrating that recycled PP yarns can be reused in textile structures with acceptable performance while contributing to waste reduction. Similarly, Lukoschek et al. [4] reported that post-consumer polypropylene waste can be successfully processed into fibers by melt spinning, and that mechanical properties comparable to virgin materials can be achieved when appropriate processing and drawing parameters are applied. Frankenbach et al. [5] further confirmed the feasibility of producing multifilament yarns from mechanically recycled polypropylene, highlighting its potential for textile applications within a circular economy framework.

Studies on the effect of recycled polypropylene content on mechanical performance can also be found in the literature. Dönmez and Kebeli [6] investigated spunbond fabrics produced from blends of virgin and recycled PP granules and observed a decrease in tensile strength with increasing r-PP content, which was attributed to polymer degradation and changes in melt flow behavior. Similarly, Rokbi et al. [7] demonstrated that processing parameters significantly influence the tensile properties of recycled polypropylene-based materials, emphasizing the importance of material and process optimization when recycled content is increased.

Despite these studies, research focusing on the use of recycled polypropylene yarns specifically in woven upholstery fabric structures remains limited. In particular, the combined effects of r-PP blending ratio, yarn characteristics, and fabric construction parameters on tensile strength have not been systematically optimized. Therefore, there is a clear need for studies that not only evaluate the mechanical performance of r-PP-containing upholstery fabrics but also determine the optimum recycled polypropylene blending ratio through experimental testing and statistical modeling.

Polypropylene is widely used in the plastic and textile industries due to its low cost, low density, high strength, chemical resistance, and ease of processing [8]. In textile applications, polypropylene fibers are commonly employed in carpets, upholstery fabrics, curtains, and filling materials, owing to their light weight, stain resistance, and moisture resistance. An additional advantage of polypropylene is its recyclability, as it can be repeatedly reprocessed through melting and reshaping [9]. In this study, filament yarns containing recycled and virgin polypropylene at different blending ratios were produced and used as weft yarns in woven upholstery fabrics. The tensile performance of the produced fabrics was evaluated according to relevant standards, and a statistical modeling approach was employed to optimize the tensile strength with respect to recycled polypropylene content. The developed model enables the prediction of fabric tensile performance and related physical properties without the need for extensive trial production, thereby supporting the efficient and sustainable use of recycled polypropylene in upholstery fabrics.

2. Materials and Methods

2.1. Materials and Yarn/Fabric Production

Virgin polypropylene (v-PP) and recycled polypropylene (r-PP) granules used in this study were supplied by a commercial manufacturer located in Istanbul, which is actively engaged in filament yarn and woven upholstery fabric production. The v-PP granules consisted of 100% polypropylene, while the r-PP granules were obtained from mechanically recycled polypropylene-based textile wastes, mainly including carpet and yarn production residues. Prior to filament yarn production, both v-PP and r-PP granules were used as

received, without any additional chemical modification or compounding. The r-PP/v-PP blends were prepared at predetermined weight ratios for filament yarn extrusion. In the experimental study, firstly virgin polypropylene (v-PP) and recycled (r-PP) granules were subjected to MFI (melt flow index) test. The MFI test is a measure of the flowability of molten polymer under specified temperature and load conditions. In the study, the amount of material flow in both samples at 230 °C and under a load of 2.16 kg in 10 min was determined according to the ASTM D1238 standard [10]. Afterwards, using the melt spinning method, FDY (fully drawn yarn) yarns containing recycled and virgin PP in different blend ratios were produced. An FET100 brand laboratory type melt spinning machine was used in the study. The spinneret L/D ratio is 4. The production parameters of the machine are shown in Table 1.

Table 1. Production parameters of filament yarns.

Extruder parameters	Zone-1 Temperature	210 °C
	Zone-2 Temperature	215 °C
	Zone-3 Temperature	225 °C
	Zone-4 Temperature	240 °C
	Extruder Speed	20.1 rpm
	Extruder Pressure	110 bar
	Pump Speed	18 rpm
Drawing unit parameters	Godet-1 Speed	300 mpm
	Godet-2 Speed	650 mpm
	Godet-3 Speed	975 mpm
	Winder Speed	1000 mpm

Filament yarn production was carried out by using recycled (r-PP) granules in different blend ratios. All yarns were produced in 195 dtex/36 filament non-interlaced, fixed fineness and fiber sections were round. In the production plan, r-PP/v-PP blend ratios are 0/100, 10/90, 20/80, and 30/70, respectively. However, it was not possible to produce filament yarns with an r-PP/v-PP blend ratio of 30/70. Filament yarn production could not be achieved when the r-PP content exceeded 20%, as the increased recycled polypropylene content led to frequent filament breakage during fiber drawing. The air jet texturing process was applied to the produced yarns and then used as weft yarn in upholstery fabric samples. While determining the yarn fineness, the product range of the company that produced the upholstery fabrics was examined and the yarns were folded. As a result of the folding process, 780 and 1170 dtex filament yarn fineness were obtained. Before moving on to fabric production, a breaking strength test was applied to the yarns. Before the test, the filament yarns were conditioned for 24 h under standard atmospheric conditions of 20 ± 2 °C and $65 \pm 2\%$ relative humidity, in accordance with ISO 139 [11]. TS EN ISO 2062 standard [12] was taken as basis in the measurement of the yarns' strength values and Zwick/Roell testing device was used. As a result of the analysis, the strength values were determined as cN/tex [12].

In the upholstery fabrics, commercially available virgin PET (polyester) filament yarns (333 dtex, 33 ends/cm) were used as warp yarns. In the weft direction, filament yarns of 780 and 1170 dtex were woven at 14 and 7 picks/cm, respectively. In order to determine the effect of using different amounts of recycled PP in the weft yarns with different fineness on strength, the parameters in the warp direction were kept constant. Six different types of plain textured upholstery fabric samples were produced with six different weft yarns.

In samples with fabric codes 780-V and 1170-V, the weft yarn contains 100% virgin PP; in samples with fabric codes 780-R10 and 1170-R10, the weft yarn contains 10% r-PP; in samples with 780-R20 and 1170-R20, the weft yarn contains 20% r-PP. The technical specifications of the fabric samples to be produced are shown in Table 2 below.

Table 2. Technical properties of upholstery fabrics.

Fabric Code	r-PP/v-PP Blend Ratio in Weft Yarn Structure (%)	Weft Yarn Fineness (dtex)	Weft Density (ends/cm)	Warp Yarn Fineness and Raw Material	Warp Density (ends/cm)	Weave Type	Weight (g/m ²)
780-V	0/100	780 dtex	14	333 dtex/PES	33	Plain	252
780-R10	10/90	780 dtex	14	333 dtex/PES	33	Plain	253
780-R20	20/80	780 dtex	14	333 dtex/PES	33	Plain	243
1170-V	0/100	1170 dtex	7	333 dtex/PES	33	Plain	218
1170-R10	10/90	1170 dtex	7	333 dtex/PES	33	Plain	215
1170-R20	20/80	1170 dtex	7	333 dtex/PES	33	Plain	207

Upholstery fabrics were woven on a Dornier rapier loom in a textile factory operating in Istanbul. In the weaving machine, the produced filament yarns were used as weft yarns and the weaving process was carried out in sections of approximately one and a half meters. The technical values and machine parameters of the produced woven fabrics are given in Table 3.

Table 3. Weaving machine production parameters of upholstery fabrics.

Loom speed	465 r/min
Width of weaving machine	160 cm
Width of fabric	140 cm
Weave type	Plain
Weft yarn type	Polypropylene yarn
Warp yarn type	Polyester yarn
Weft yarn fineness	780 ve 1170 dtex
Warp yarn fineness	333 dtex
Weft density	14 and 7 ends/cm
Warp density	33 ends/cm

2.2. Fabric Testing and Statistical Analysis

In the study, in order to determine the effects of recycled polypropylene (r-PP) yarn in the structure of upholstery fabrics on the breaking strength, tearing strength, seam slippage, pilling, and abrasion resistance of the fabrics, fabric tests in accordance with TS EN ISO 13934-1, TS EN ISO 13937-3, TS EN ISO 13936-2, TS EN ISO 12945-2, and TS EN ISO 12947-2 standards were applied and the results were interpreted [13–17]. Fabric breaking strength was carried out according to the relevant standard. The force was applied to sample fabrics with jaws for the determination of fabric breaking strength. It was aimed to determine the force value that causes breaking in the sample [13]. The results were also evaluated statistically in the study. IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses. When selecting the statistical analyses to be applied to the data, it should first be checked whether the data

are suitable for normal distribution. It is necessary to pay attention to five parameters in order to determine whether the data correspond to the normal distribution. These are histogram graphs, coefficients of variation, skewness and kurtosis values, detrended normal Q-Q graph, and normality of tests. If at least three of these five parameters conform to normal distribution values, it is understood that the data show normal distribution [18]. Analysis of variance (ANOVA) was performed at a significance level of 0.05 to determine the significant effects of r-PP/v-PP blend ratio and weft yarn fineness on fabric performance properties. In the study, regression analyses were performed to determine the objective function and constraint equations of the optimization model. With the help of the variance analyses, explanatory variables affecting each dependent variable in the regression analyses were easily determined. In addition, performance results were calculated using regression equations and the relationship between these values and the test results was also examined. The relationship between the calculated results and the measured results was found to be statistically significant at the 99% confidence level.

2.3. Statistical Modeling and Optimization Procedure

In this study, a statistical modeling and optimization approach was applied to quantify the effects of recycled polypropylene content and weft yarn fineness on fabric tensile strength and to determine optimum production conditions. Multiple linear regression analysis was used to establish the relationship between the dependent variable and the selected independent variables. Fabric tensile strength was considered as the response variable, while r-PP/v-PP blend ratio and weft yarn fineness were selected as explanatory variables based on the experimental design. The general form of the regression model used in this study is given in Equation (1):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon \quad (1)$$

where Y represents the fabric tensile strength (N), X_1 donates the r-PP/v-PP blend ratio, X_2 represents the weft yarn linear density, β_0 is intercept, β_1 and β_2 are the regression coefficients, and ε is random error term.

Analysis of variance (ANOVA) was conducted to evaluate the statistical significance of the regression model and to determine the contribution of each independent variable to the response. The F-test was used to assess the overall model significance at a confidence level of 95% ($p < 0.05$). Variables with statistically significant effects were included in the final regression equations used for optimization. Based on the regression models, an optimization procedure was performed with the objective of maximizing fabric breaking strength under feasible production conditions. The optimization problem can be expressed as follows:

Maximize Y

subject to

- r-PP/v-PP blend ratios enabling stable filament yarn production,
- selected weft yarn fineness levels used in upholstery fabric manufacturing.

To validate the optimization model, fabric tensile strength values calculated from the regression equations were compared with experimentally measured results. Pearson correlation analysis was performed to evaluate the relationship between predicted and measured values, and a statistically significant correlation at the 99% confidence level confirmed the reliability of the proposed model.

3. Results and Discussion

The melt flow index (MFI) of virgin and recycled polypropylene granules was determined prior to filament yarn production to evaluate their flow characteristics. Measurements were performed at 230 °C with a load of 2.16 kg following ASTM D1238. The MFI values of the virgin polypropylene (v-PP) and recycled polypropylene (r-PP) granules were determined as 22.58 g/10 min and 53.32 g/10 min, respectively. Accordingly, an increase in the r-PP/v-PP blend ratio results in a gradual increase in the melt flowability of the weft yarn material. The increase in MFI indicates a reduction in the molecular weight of r-PP, which can be attributed to chain scission and molecular degradation occurring during the recycling process. It has been widely reported in the literature that recycling-induced degradation in polypropylene leads to increased MFI values and reduced molecular weight, adversely affecting mechanical performance and process stability [19,20]. The higher flowability observed for r-PP in the present study is consistent with the processing difficulties and filament breakage encountered at higher r-PP blending ratios during yarn production.

In the production plan of the study, the r-PP/v-PP blend ratios were 0/100, 10/90, 20/80, and 30/70. However, yarn production could not be achieved for the blend containing 30% r-PP. Increasing the r-PP/v-PP ratio significantly alters the melt flow behavior of the polymer blend during melt spinning. Higher recycled content often results in reduced molecular entanglement density and altered crystallization behavior, leading to decreased melt strength and stability under elongational stress during filament formation, which has been linked to flow-induced crystallization suppression in recycled polypropylene relative to virgin materials [20]. Moreover, studies have shown that increasing r-PP content improves melt fluidity but may decrease oxidative stability and mechanical ductility, indicating a trade-off between processability and structural integrity at high recycled levels [21].

In the experimental study, the breaking strengths of filament yarns produced for use in weft yarns of upholstery fabrics were determined. As a result of the test, the strength values of 780 dtex v-PP; 10/90 r-PP/v-PP and 20/80 r-PP/v-PP yarns were 15.3; 13.8 and 13.3 cN/tex, respectively. The strength values of 1170 dtex v-PP; 10/90 r-PP/v-PP and 20/80 r-PP/v-PP yarns were 16; 12.6 and 10.9 cN/tex, respectively. It is observed that the breaking strength of filament yarns containing v-PP is higher. It is thought that the bond between the polymers weakens with the increase in the r-PP ratio and as a result, there is a decrease in strength [3]. However, during recycling processes applied to polypropylene, deterioration in the physical and chemical properties of fibers may occur due to contamination by foreign substances and repeated thermal–mechanical degradation. In the present study, melt flow index (MFI) and differential scanning calorimetry (DSC) analyses were performed on both virgin and recycled polypropylene granules to evaluate changes in flow behavior and thermal properties. Differences observed in these analyses indicate molecular degradation in recycled polypropylene, which may lead to a reduction in yarn strength, as also reported in the literature [22,23].

The produced yarns were used in the weft to obtain plain textured upholstery fabrics. First, the tensile strength of the fabrics was determined. In all fabric samples, the warp yarn fineness, fiber type (333 dtex polyester yarn), and warp density (33 ends/cm) were kept constant. The tensile strength in the warp direction was consistently higher than that in the weft direction and exceeded 1090 N. Since the warp yarns used in upholstery fabrics have a strong structure, are under constant tension during production on the loom, and the warp densities are higher than the weft densities, the warp direction breaking strengths in the fabric samples were obtained at high values.

The weft direction breaking strength values of the fabric samples are shown in Figure 1. The fabric types produced using 780 dtex fineness yarn in the weft have higher breaking

strength compared to the fabrics produced using 1170 dtex. Since two different weft yarn fineness values were used in the study, it was necessary to reduce the weft density slightly while using 1170 dtex weft yarns in order to obtain a suitable structure during weaving. In fabrics where 1170 dtex is used in the weft, the weft breaking strength is slightly lower because the weft density is halved. As the density increases, the contact area between the weft and warp yarns increases. Therefore, it is expected that the strength will be higher in fabrics where the weft density is 14 [24]. In addition, with the increase in the r-PP ratio in the yarns used in the weft, a slight decrease in fabric strength in the weft direction was observed. When the strengths of the yarns used in the weft are examined, it is seen that the highest yarn strengths are v-PP yarns that do not use r-PP. In recycled fibers, the bonds between polymers are weaker and the fiber molecular weight is lower [3,22,25]. Since yarn strength also affects fabric strength, when fabric types with weft yarn fineness of 780 and 1170 dtex were examined among themselves, it was seen that the highest fabric strength value was in fabrics coded 780-V and 1170-V, that is, fabrics that do not contain r-PP in their structure.

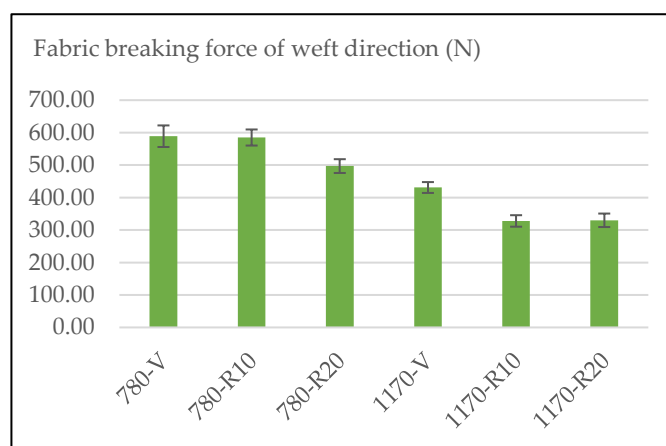


Figure 1. Breaking force values of weft direction.

Two-way ANOVA was performed to see the effect of some production parameters on weft breaking strength. The analysis results are shown in Table 4. When the results are examined, it is seen that filament fineness and r-PP/v-PP blend ratio have a statistically significant effect on weft breaking strength (Sig. (p) < 0.05). When the effects of filament fineness and blend ratio on weft breaking strength were examined together, a statistically significant relationship was found (Sig. (p) < 0.05). In addition, since the parameters such as warp yarn fineness, warp yarn raw material, and warp density were constant in all fabrics and the warp direction fabric strength was above 1090 N, it was not necessary to statistically examine the effect of independent variables on the warp direction breaking strength. As seen in Table 2, the weft density is higher in fabrics with 780 dtex weft yarn. In order to obtain a solid structure in the fabrics during weaving, when the weft yarn fineness changes, the weft density also changes. Therefore, only the weft yarn fineness and blend ratios were taken into account in the variance analyses. Otherwise, a multicollinearity problem occurs [26].

By also using the variance analysis results, the r-PP/v-PP blend ratio (BR) and weft yarn fineness (WF) variables of the weft yarn, which have an effect on the weft breaking strength, were determined and used in regression analyses. The regression analysis results of the weft breaking strength dependent variable are shown in Table 5. The equation obtained from the analysis results in question was used as the objective function in the optimization model. Similarly, other equations in the constraints were obtained by regression analyses by determining the independent variables that may have an effect on

each dependent variable. The objective function and constraints used in the mathematical model created with the help of regression equations are shown in Table 6. The lower and upper limit values in the table were determined by test standards and literature reviews. In addition, dummy variables were created for the categorical variables BR and WF in the regression analyses. Since the study aimed to promote the use of recycled polypropylene (r-PP), only the parameters of fabrics containing r-PP were included in the modeling. In the analysis, fabrics produced with 20% r-PP weft yarns were coded as “1”, while those with a 10% r-PP blend ratio were coded as “0”. Similarly, fabrics woven with 780 dtex weft yarns were coded as “1”, whereas those with 1170 dtex weft yarns were coded as “0”.

Table 4. Two-way ANOVA results for weft breaking strength.

Performance Property	Source		df	F	Sig.(p)
Weft Breaking Strength	Main effect	Blend ratio	2	65.887	0.000 *
		Weft yarn fineness	1	796.750	0.000 *
	Interaction	Blend ratio * Weft yarn fineness	2	21.201	0.000 *

* Statistically significant (5% significance level).

Table 5. Regression analysis results of the dependent variable of weft breaking strength.

Independent Variables	Coefficient	t Value	Sig.(p)
Constant	350.550	30.241	0.000
Weft yarn fineness	211.900	15.831	0.000
Blend ratio	−42.900	−3.205	0.005

Table 6. Objective function and restrictive equations used in the optimization model.

	Constraints	Lower Limit	Upper Limit
Weft tear strength (N)	$WETS = 79.300 + 19.200 \times WF - 8 \times BR$	15	-
Warp seam slippage (mm)	$WASS = 5.423 - 4.355 \times WF + 0.155 \times BR$	-	6
Abrasion resistant (Cycle)	$AS = 41,250 - 7500 \times BR + 12,500 \times WF$	20,000	-
Weft fineness	WF	0	1
Blend ratio	BR	0	1
Objective function			
Weft breaking strength (N)	$WEBS = 350.550 + 211.900 \times WF - 42.900 \times BR$		

In the study, an optimization model was created with the aim of maximizing the weft breaking strength with the help of regression equations. All data were formatted according to the requirements of Lingo Optimization Modeling Software, Version 18.0 (Lindo Systems Inc., Chicago, IL, USA), and the software generated the solution report. According to the solution report, the problem resulted in the ‘Global Optimum’ solution. This result means that the best solution was obtained in line with the constraints. The Objective Value or in other words the maximum weft breaking strength value is 562.45 N. In the Solution report given by the Lingo program, all variables belonging to the model are seen in the ‘Variable’ column. The values of the variables in the model in the global optimum solution are seen in the ‘Value’ column. The optimum values of all variables in the model depending on the maximum weft breaking strength value in the fabrics are seen in Table 7.

Table 7. Solution results of the WEBS maximization model.

Variables	Optimum Values
Weft tear strength (WETS)	98.5 N
Warp seam slippage (WASS)	1.068 mm
Abrasion resistant (AS)	53,750 cycles
Weft fineness (WF)	780 dtex
Blend ratio (BR)	10% r-PP
Maximum weft breaking strength (WEBS)	562.45 N

In addition, performance results for each fabric sample were calculated using equations obtained from regression analyses, and the relationship between these values and the values measured in the tests was revealed. For this purpose, the correlation analysis shown in Table 8 was performed.

Table 8. Correlation analysis results.

		Measured_WEBS	Measured_WETS	Measured_WASS	Measured_AS
Calculated_WEBS	Pearson Correlation	0.957 **	0.311	−0.963 **	0.715
	Sig. (2-tailed)	0.003	0.549	0.002	0.110
Calculated_WETS	Pearson Correlation	0.573	0.600	−0.393	0.919 **
	Sig. (2-tailed)	0.234	0.208	0.441	0.010
Calculated_WASS	Pearson Correlation	−0.929 **	−0.173	0.992 **	−0.542
	Sig. (2-tailed)	0.007	0.743	0.000	0.267
Calculated_AS	Pearson Correlation	0.724	0.572	−0.578	0.940 **
	Sig. (2-tailed)	0.104	0.235	0.230	0.005

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

As shown in Table 8, the relationship between the results calculated using regression equations and the test results was found to be statistically significant with 99% confidence. In other words, a high level of correlation was determined between the calculated and measured values, and this correlation was statistically significant with 99% confidence.

4. Conclusions

Polypropylene is a material used in home textiles. In the textile industry, it is preferred due to its lightweight and durable structure, resistance to stains and moisture, colorfastness, hypoallergenic properties, and low production costs. Given the environmental impact of the textile industry, recycling and sustainable practices are essential. Employing circular material flow systems and extending product life cycles enhance environmental benefits [27]. This study is an important study in terms of the spread of sustainable and environmentally friendly production, the use of recyclable materials in the textile sector, and the reduction in economic loss and production costs. The study is expected to contribute especially to the home textile sector since polypropylene material is preferred in the sector, especially in carpet production, upholstery fabrics, bedding fabrics, and outdoor textiles. However, polypropylene material has some inherent drawbacks and limitations (difficulty in dyeing, stiffness, low heat resistance, pilling, etc.) [28]. In upholstery fabrics produced entirely from polypropylene yarns in both warp and weft directions, dyeing-related limitations

may be encountered. Therefore, in this study, polyester yarns were deliberately used in the warp direction, while r-PP and v-PP filament yarns were used in the weft, with the aim of mitigating potential dyeing-related issues and improving overall fabric performance. Although the effects of this material combination on dyeability and thermal properties were not experimentally investigated in this study, these aspects are considered important topics for future research [29].

In this study, weft yarns produced from virgin and recycled polypropylene granules in different blend ratios were used in upholstery fabrics, and their tensile strengths were evaluated. An optimization model was applied to maximize weft tensile strength and predict key performance properties before production. The results obtained in the study are summarized below:

- Weft tensile strength values are affected by the r-PP/v-PP blend ratio and weft yarn fineness, with higher r-PP content generally causing a slight decrease in strength.
- According to TS 11,818 EN 14465, the minimum tensile strength value of upholstery fabrics is required to be 250 N [30]. It is seen that all fabrics have sufficient strength values.
- Variance analysis confirmed that both the blend ratio and yarn fineness significantly affected weft breaking strength ($\text{Sig.}(p) < 0.05$).
- The optimal weft properties determined by the model were 780 dtex yarn with a 10/90 r-PP/v-PP blend, yielding a predicted breaking strength of 562.45 N, tearing strength of 98.5 N, abrasion resistance of 53,750 cycles, and warp seam slippage of 1.068 mm.
- The regression-based model allows the prediction of physical and performance properties before production, reducing the need for trial runs and associated costs, and can be adapted in future studies to optimize other performance parameters such as abrasion resistance or seam slippage.

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