



INVESTIGATION OF THE PHYSICAL AND MECHANICAL PROPERTIES OF COTTON FABRICS WITH DIFFERENT WEAVE STRUCTURES

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Abstract: Cotton fabrics represent one of the most commonly used groups of textile materials due to their favorable combination of mechanical, functional, and comfort-related properties. These properties largely depend on the structural parameters of the fabric, among which the weave structure plays a significant role. The interlacing pattern of warp and weft yarns determines the geometry of the fabric, the structural density, and the pore distribution, which directly affect its physical–mechanical and functional properties. The aim of this study is to investigate the influence of different weave structures on selected physical and mechanical properties of cotton fabrics. The research analyzed fabrics produced in three different weave structures: Panama, twill, and longitudinal rib. The following fabric properties were examined: thickness, breaking strength and elongation at break, dimensional stability, abrasion resistance, porosity, capillarity, and air permeability. Experimental testing was carried out using standardized methods for testing textile materials. The obtained results indicate that the weave structure significantly affects the mechanical behavior and functional characteristics of cotton fabrics. The results of this research contribute to a better understanding of the relationship between fabric structure and its properties and may serve as a basis for optimizing fabric construction according to their intended use and required functional characteristics.

Key words: woven product, panama, twill, warp rib, physical and mechanical properties.

1. INTRODUCTION

Textile materials play an important role in modern society due to their wide range of applications in clothing, household products, technical textiles, and various industrial fields. Among the numerous natural fibers used in textile production, cotton occupies a prominent position because of its favorable properties, such as high moisture absorbency, comfort, softness, breathability, and relatively good mechanical performance. Owing to these characteristics, cotton fabrics are extensively used in the production of apparel and home textiles, which makes the investigation of their physical and mechanical properties particularly important for both textile engineering and practical applications [1, 2].



The properties of woven fabrics are largely determined by their structural characteristics, especially by the manner in which warp and weft yarns interlace. The type of weave significantly affects the arrangement of yarns within the fabric, the structural density, the contact area between fibers, and the distribution of stress when the material is subjected to mechanical loads. Consequently, different weave structures can substantially influence the physical and mechanical characteristics of fabrics, including strength, elongation, abrasion resistance, and functional properties such as air permeability, porosity, and dimensional stability. Among the commonly used weave structures in cotton fabrics are the Panama weave, twill weave, and rib weaves. The Panama weave is characterized by the grouping of warp and weft yarns, which creates a distinctive texture and usually results in a more open fabric structure with relatively larger pores. The 2/2 twill weave is recognizable by its diagonal lines on the fabric surface and provides a favorable distribution of mechanical stress within the structure, often leading to improved mechanical properties and higher resistance to abrasion. In contrast, the longitudinal rib weave forms pronounced longitudinal ribs, which can influence the fabric's thickness, stiffness, and structural stability [3, 4].

The physical and mechanical properties of fabrics represent important parameters that determine their functionality, durability, and overall quality. Fabric thickness affects thermal insulation, weight, and comfort of the material. Breaking strength and elongation at break indicate the ability of the fabric to withstand mechanical stresses during use. Dimensional stability reflects the ability of the fabric to maintain its original dimensions after exposure to moisture, heat, and mechanical forces. Abrasion resistance is another important parameter that determines the durability of textile materials under repeated friction during wear and use [5, 6].

In addition to mechanical characteristics, several functional properties significantly influence the comfort and performance of textile materials. Fabric porosity and air permeability determine the degree of air circulation through the material and play a crucial role in thermophysiological comfort. Capillarity describes the ability of a fabric to transport liquid through its structure, which is particularly important for clothing materials and technical textile applications. The tendency of fabrics to wrinkle affects their aesthetic appearance as well as the practicality of maintenance and use [7, 8].

Considering that the structural characteristics of woven fabrics have a significant influence on these properties, it is important to systematically investigate the effect of different weave structures on the performance of cotton fabrics.

In this study, cotton fabrics with three different weave structures are examined: Panama weave, 2/2 twill weave, and longitudinal rib weave. The analyzed properties include thickness, breaking strength and elongation, dimensional stability, abrasion resistance, porosity, capillarity, air permeability, and wrinkle behavior.

The aim of this research is to determine the influence of weave structure on the physical and mechanical properties of cotton fabrics and to provide results that contribute to a better understanding of the behavior of textile materials, as well as to support the optimization of fabric structure selection according to the intended application.

2. EXPERIMENTAL PART

The grey fabrics used in this investigation were produced from 100% cotton yarns with similar values of yarn fineness (linear densities of the yarns) and thread densities in both the warp and weft directions, but with different weave structures. The structural properties of the investigated fabrics are presented in Table 1.



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Table 1: Declared values of the main properties of grey cotton fabrics.

Yarn linear density (tex)		Thread density (cm ⁻¹)		Fabric mass (g/m ²)	Weaves
Warp	Weft	Warp	Weft		
36	34	29	22	180	Panama
35	34	28	21	175	2/2 Twill
36	35	28	20	177	Warp rib

The weaving process was carried out on PICANOL looms with a maximum working width of 180 cm. The machine capacity is 240 picks per minute, depending on the fabric density being produced. The loom is equipped with a semi-automatic control unit with one operating speed, while the installed power is 1.4 kW.

Testing methods:

- Fabric thickness, according to the standard SRPS EN ISO 5084:2013.
- Dimensional change, according to the standard SRPS EN ISO 6330:2022.
- Breaking force and elongation of fabrics, according to the standards SRPS EN ISO 13934-1:2015 and SRPS EN ISO 13934-2:2012.
- Abrasion resistance, according to the standard SRPS EN ISO 12947-2:2017.
- Capillarity, according to the standard SRPS F.S2.042:1985.
- Air permeability, according to the standard SRPS EN ISO 9237:2010.
- Fabric porosity, determined using the cover factor, according to the standard SRPS EN ISO 7211-2:2024.

3. RESULTS AND DISCUSSION

The obtained experimental results indicate that the weave structure has a significant influence on the physical and mechanical properties of cotton fabrics. Overall, the results confirm that variations in weave structure lead to significant changes in fabric geometry and consequently influence the mechanical and functional performance of cotton fabrics. Namely, if the linear densities of the yarns (fineness) and the thread densities in both warp and weft are very similar for all three fabrics, then the tested properties are primarily influenced by the type of weave, i.e., by the manner in which the yarns interlace [9, 10].

The results of the thickness change of the cotton samples of the analyzed fabrics are presented in Table 2. Among other factors, fabric thickness is significantly influenced by the type of weave, since the weave determines the manner of yarn interlacing and bending within the fabric structure. In fabrics with approximately the same yarn fineness and similar thread densities, the panama weave usually results in greater thickness due to the grouped interlacing of yarns and a more pronounced volumetric structure. The 2/2 twill exhibits intermediate thickness values, whereas the warp rib structure, due to the greater compactness of yarns in the fabric structure, most often shows lower thickness values.

According to the results, depending on the weave structure, the mean fabric thickness varies between 0.25 and 0.28 mm, with a very small standard error ranging from 0.0058 to 0.0068 mm.

The standard error indicates the extent to which the mean values of fabric thickness may vary. Since the values of this statistical parameter are very low, it can be concluded that the mean value is highly reliable, the measurements are consistent, and the mean thickness adequately represents the entire series of samples.

Low values of the standard deviation in this case confirm that the measurements are very similar and consistent. This parameter indicates the homogeneity of the material and the stability of



the measurements. The coefficient of variation is a relative measure of variability and therefore enables comparison between different parameters. The numerical values of this statistical parameter for thickness indicate a moderate variation of the results and a moderate uniformity of the tested fabric samples.

The panama weave is characterized by grouped yarn interlacings, which create a more pronounced and fuller structure; therefore, the fabric is usually thicker and more voluminous. The twill weave has a diagonal structure and fewer interlacing points than the plain weave, resulting in a moderate fabric thickness. The warp rib weave exhibits pronounced rib lines in the warp direction, but a more compact structure; consequently, it is usually the thinnest when the other parameters are identical or similar.

The standard deviation (SD) for the examined parameter ranges from 0.018 to 0.022 mm, while the coefficient of variation (CV) reaches values between 7.0 and 7.8%.

Table 2: Thickness results of grey fabrics with different weave structures

Statistical parameters	Thickness		
	Panama	Twill	Warp rib
Mean value (mm)	0.28	0.26	0.25
Standard error (mm)	0.0068	0.0058	0.0061
Standard deviation (mm)	0.022	0.018	0.019
Coefficient of variation (%)	7.7	7.0	7.8

Dimensional stability of fibers, yarns, and textile products when brought into contact with hot water or hot solutions is an important indicator of their quality. The requirements regarding the dimensional stability of textile materials are that shrinkage should be as low as possible. In practice, however, it is usually difficult to ensure that a textile material does not change its dimensions to a certain extent [11].

According to Figure 1, it can be observed that after the dimensional change test, shrinkage of the fabric samples occurs for all weave structures, both in the warp direction and in the weft direction. Considering that the linear densities of the yarns and the thread densities of the fabrics are very similar, the dimensional changes (shrinkage) are mainly influenced by the type of weave, i.e., by the number of interlacing points and the yarn waviness (crimp) within the fabric structure.

Fabrics with a twill weave exhibit greater shrinkage due to the smaller number of binding points and the higher mobility of the yarns, whereas fabrics with a panama weave show moderate dimensional changes. The highest dimensional stability is observed in fabrics with a warp rib weave, owing to the greater binding and compactness of the structure.

It is noticeable that the fabric samples exhibit uniform and low values of statistical parameters in both directions. For all fabric weave structures and for the tested parameter of shrinkage, the standard error ranges from 0.073 to 0.098%, the standard deviation (SD) from 0.23 to 0.31%, while the coefficient of variation (CV) ranges from 7.4 to 11.1%.

The weft shrinkage in panama fabrics is slightly higher than in the warp direction because the weft has a higher crimp, experiences lower tension during weaving, and the panama weave structure is relatively looser. In addition, the relaxation of cotton fibers during washing increases the shortening of the yarns, etc.

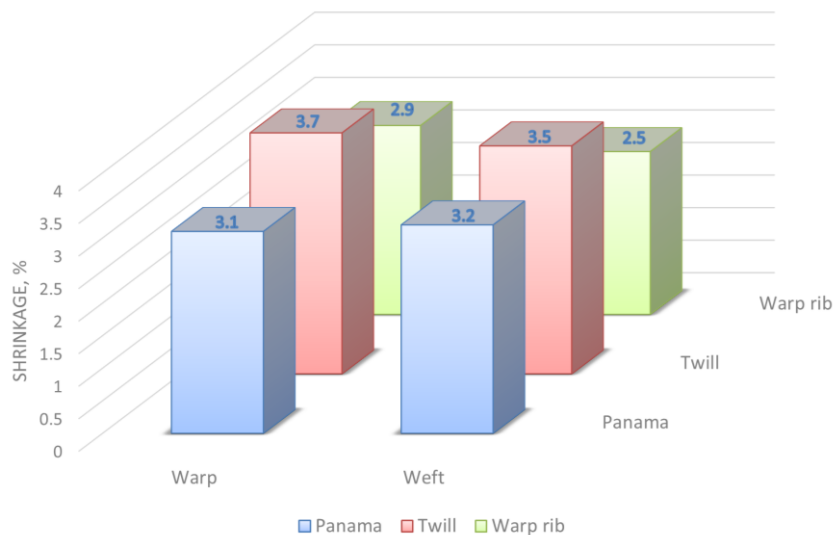


Fig. 1: Dimensional changes of fabrics with different weave structures

Mechanical properties of textile materials are highly significant, particularly breaking strength and elongation. These properties determine the quality and performance characteristics of the final textile product.

Figures 2 and 3 present the results of the breaking strength and elongation at break of the analyzed fabrics. The test results indicate that the type of weave structure has a significant influence on the breaking strength and elongation at break of the investigated cotton fabrics.

The twill weave exhibits the highest values of breaking strength in both the warp and weft directions, amounting to 485 N and 350 N, respectively. In contrast, the fabric with a rib weave shows the lowest breaking strength values, reaching 465 N in the warp direction and 333 N in the weft direction, respectively.

The highest measurement error for this parameter is observed in the rib weave fabric in the warp direction, amounting to 7.7 N, while the lowest error is recorded for the panama weave fabric, 6.0 N. The standard deviation (SD) of the same parameter ranges from 16.3 N (weft direction, panama weave) to 24.5 N (warp direction, rib weave). Regarding the coefficient of variation (CV), the values range from the highest value of 5.9% (weft direction, twill weave) to the lowest value of 4.0% (warp direction, panama weave).

Relatively low values of the standard error indicate that the mean value of the breaking strength has high reliability. The standard deviation, as a statistical parameter describing the dispersion of individual measurements around the mean, implies a certain variation of the results, which is common for textile materials due to the non-uniformity of fabric structure. The coefficient of variation, as a relative measure of variability and the best indicator of the uniformity of results, shows through its numerical values that the results are well balanced and that the fabric samples are relatively homogeneous.

The twill weave has fewer binding points and longer yarn floats, which allows the load to be distributed more uniformly, resulting in higher breaking strength. The panama weave is characterized by grouped yarn interlacings, which somewhat increases the structural rigidity, leading to intermediate strength values. The warp rib weave has a larger number of interlacings within one yarn system, which increases yarn bending and local stresses, and consequently results in the lowest breaking strength.

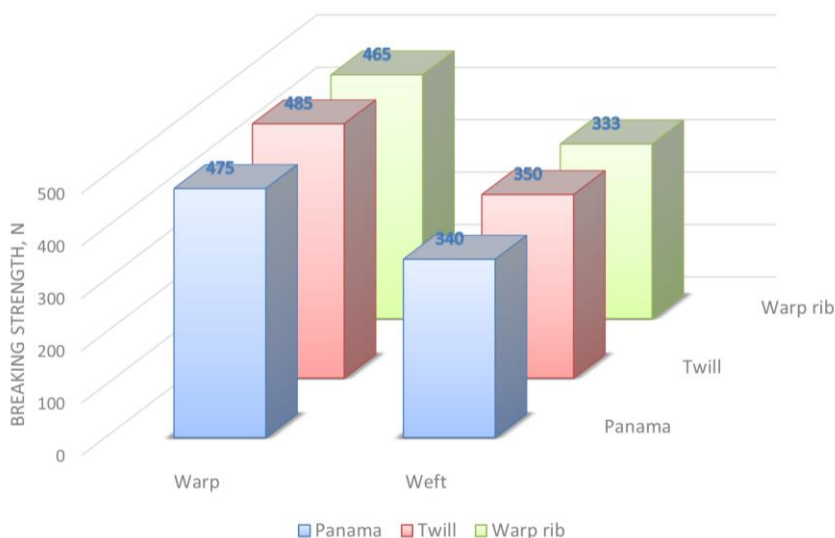


Fig. 2. Changes in the breaking strength of fabrics with different weave structures

According to Figure 3, the elongation at break of the fabrics in all weave structures varies from 10% (warp direction, rib weave) to 15% (weft direction, twill weave). The statistical data are appropriate and confirm the validity of the obtained measurement values for this tested parameter.

Namely, the standard error values are relatively uniform for fabrics of all weave structures, ranging from 0.56% (weft direction, rib weave) to 0.84% (weft direction, twill weave). The standard deviation (SD) varies from 1.49% (warp direction, twill weave) to 2.67% (weft direction, twill weave). The coefficient of variation (CV) ranges from the lowest value of 0.13% to 0.23%.

The twill weave has a longer wavy yarn path (higher crimp), allowing the fabric to elongate more before rupture. The panama weave exhibits moderate elongation due to the grouping of yarns. The warp rib weave has a greater number of interlacing points and limited yarn mobility, resulting in the lowest elongation at break.

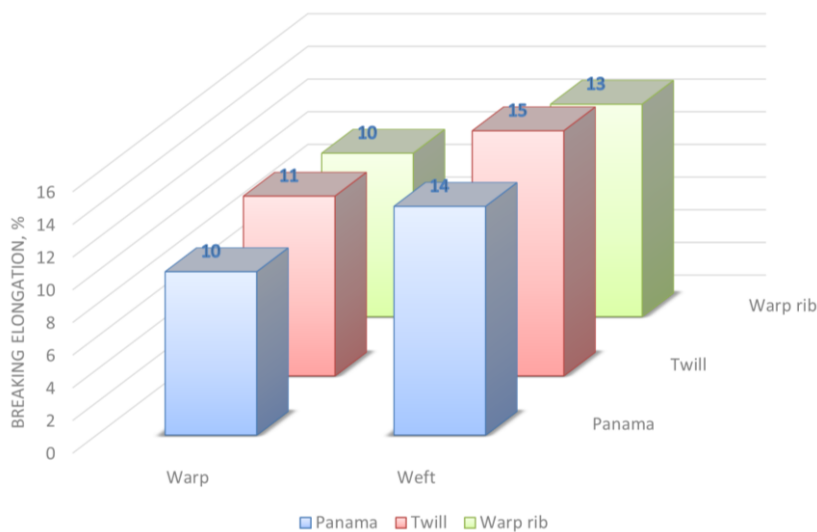


Fig. 3: Changes in the breaking elongation of fabrics with different weave structures



Abrasion resistance determines the behavior of a fabric under different conditions of use as well as its service life. This characteristic is equally important for all types of fabrics, including apparel fabrics, decorative fabrics, and fabrics for special applications [12].

According to Table 3, a loss of fabric mass is observed in all cases, with mean values ranging between 3.4% and 4.9%. Fabrics with rib and twill weaves exhibit the highest and the lowest mass loss after abrasion, respectively.

The statistical parameters follow the mean values of this investigated parameter. The standard error is the lowest for the twill weave sample (0.26%) and the highest for the panama weave (0.33%). The standard deviation (SD) values range from 0.81% to 1.05%, while the coefficient of variation (CV) values are relatively uniform.

The twill weave has a diagonal structure and a smaller number of binding points, which allows a better distribution of mechanical load and reduces local fiber wear. For this reason, it exhibits the highest abrasion resistance. The panama weave forms a somewhat more pronounced surface and local wear points, resulting in moderate abrasion resistance. The warp rib weave is characterized by pronounced longitudinal rib lines and more frequent interlacing points, which leads to faster wear of the protruding parts of the structure; therefore, it shows the lowest abrasion resistance.

Abrasion resistance is significantly influenced by the type of weave structure. Fabrics with a twill weave exhibit higher abrasion resistance due to a more favorable distribution of load and a lower concentration of friction at specific points. Fabrics with a panama weave show moderate resistance, whereas fabrics with a warp rib weave demonstrate the lowest abrasion resistance due to the pronounced rib structure and greater localized yarn wear.

Table 3: Abrasion resistance of fabrics with different weave structures

Statistical parameters	Abrasion (mass loss after 20,000 cycles)		
	Panama	Twill	Warp rib
Mean value (%)	4,0	3,4	4,9
Standard error (%)	0.33	0.26	0.31
Standard deviation (%)	1.05	0.81	0.99
Coefficient of variation (%)	0.26	0.24	0.20

Differences in capillarity mainly arise from the geometry of the weave structure, the yarn crimp, and the continuity of capillary channels. In addition, the height of liquid rise depends on the effective radius of the capillary channels within the fabric structure [13].

According to Figure 4, the highest values of this parameter are recorded for the panama weave fabric in the weft direction (136 mm), while the lowest values are observed for the panama weave fabric in the warp direction and the rib weave fabric in the weft direction (118 mm in both cases).

Among the statistical indicators, the standard error and standard deviation (SD) for the panama and rib weave fabrics (both in the warp and weft directions) stand out, with slightly higher numerical values.

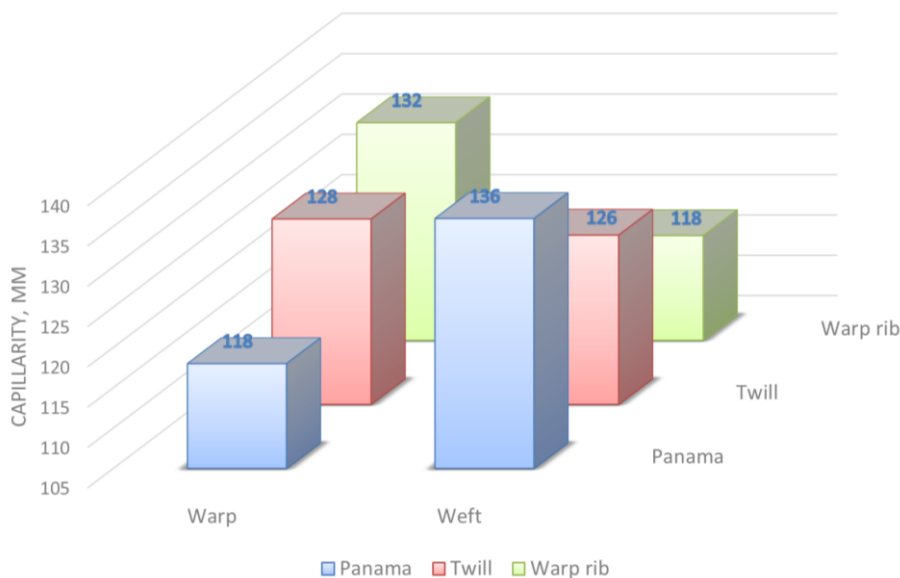


Fig. 4: Changes in the capillarity of fabrics with different weave structures

Differences in air permeability mainly arise from the geometry of the weave structure, the size and continuity of pores, the yarn crimp, and the degree of surface cover [14].

The panama (basket) weave has larger structural pores because several yarns are grouped together to form a unit. The twill weave has a diagonal structure and a somewhat more compact surface than the panama weave. In the warp rib weave, the warp yarns are positioned closer to each other and form pronounced ribs, which partially reduce the size of the pores.

According to Table 4, the twill weave fabric shows the lowest air permeability, while the rib weave fabric exhibits the highest air permeability. In addition, the standard error and standard deviation are more pronounced for these fabrics.

Table 4: Air permeability of fabrics with different weave structures

Statistical parameters	Air permeability		
	Panama	Twill	Warp rib
Mean value (L/m ² /s)	215	185	255
Standard error (L/m ² /s)	3.33	5.05	5.69
Standard deviation (L/m ² /s)	10.54	15.99	17.99
Coefficient of variation (%)	0.049	0.086	0.070

Differences in fabric porosity mainly arise from the geometry of the weave structure, the number of yarn contact points, the yarn crimp, and the manner in which the yarns are packed within the structure [15].

Panama weave exhibits the most compact structure with a larger number of smaller pores. Twill weave shows moderate porosity with pores of intermediate size, whereas the longitudinal rib weave has the most open structure, characterized by a smaller number of larger, elongated pores.

According to Table 5, the lowest porosity is observed in the panama weave fabric, while the highest porosity is recorded for the warp rib weave fabric. In addition, the standard error and standard deviation are more pronounced in the fabric with the longitudinal rib weave, while the



coefficient of variation shows low values for all three weaves. This indicates that the porosity measurement results are homogeneous, reproducible, and statistically reliable.

Panama weave may exhibit lower porosity but higher air permeability compared to twill weave because it forms larger and more direct channels for airflow, has lower tortuosity of the flow paths, and the grouping of yarns creates continuous inter-yarn pores. In twill fabrics, the diagonal structure increases the resistance to air flow.

Table 5: Porosity of fabrics with different weave structures

Statistical parameters	Porosity		
	Panama	Twill	Warp rib
Mean value (%)	69	70	74
Standard error (%)	1.05	1.04	1.22
Standard deviation (%)	3.33	3.30	3.86
Coefficient of variation (%)	0.048	0.047	0.052

5. CONCLUSIONS

In this study, the influence of weave structure on the physical–mechanical and functional properties of cotton fabrics was investigated. Fabrics produced in three different weave structures—panama, twill, and warp rib—were analyzed, and properties such as thickness, breaking strength and elongation at break, dimensional stability, abrasion resistance, porosity, capillarity, and air permeability were examined.

The research results showed that the weave structure has a significant influence on the investigated properties of fabrics. Differences in the interlacing pattern of warp and weft yarns lead to variations in the geometrical structure of the fabric, which is reflected in the mechanical behavior of the material as well as in its functional characteristics.

Fabrics with a 2/2 twill weave exhibit favorable mechanical properties, particularly in terms of breaking strength and abrasion resistance, which is a consequence of a lower number of interlacing points and a more uniform distribution of stresses within the structure. The Panama weave is characterized by relatively higher capillarity and moderate air permeability, which may contribute to improved comfort properties of the material. On the other hand, the fabric with a longitudinal rib weave exhibits a distinctive structure with pronounced ribs, which affects the fabric thickness, structural stability, as well as air permeability and porosity.

Based on the obtained results, it can be concluded that the selection of an appropriate weave structure plays an important role in the design of cotton fabrics with desired mechanical and functional properties. Understanding the relationship between weave structure and fabric properties enables the optimization of textile material construction according to their intended application, which is of great importance for the development of modern textile products.

Although the results of this study provide valuable insight into the influence of weave structure on the physical and mechanical properties of cotton fabrics, several aspects remain open for further investigation. Future research could focus on expanding the analysis to include a wider range of weave structures and fabric parameters in order to obtain a more comprehensive understanding of their influence on fabric performance.



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