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EFFICIENCY OF COTTON FABRIC DESIZING USING DIFFERENT METHODS

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Desizing of cotton fabric is a vital step in textile wet processing, directly influencing subsequent treatment and overall fabric performance. This study evaluates the effectiveness of hydrochloric acid, ammonium persulfate, and thermostable amylase asdesizing methods.. The performance of each method was assessed through key parameters: change in fabric mass, water penetration time, water absorption capacity, breaking strength, elongation at break, and air permeability. The results indicate distinct differences in the action mechanisms and effects of the desizing agents. Hydrochloric acid and ammonium persulfate demonstrated rapid sizing material removal, but also caused a noticeable reduction in mechanical properties and air permeability, which is attributed to their oxidative and acidic properties. In contrast, enzymatic desizing using thermostable amylase ensured effective removal of size material while maintaining fabric strength, elongation, and permeability characteristics. These findings support the potential of enzymatic desizing as a more fabric-friendly and sustainable alternative to conventional chemical methods, particularly for plain weave cotton substrates.

Keywords: cotton fabric, desizing, amylase, hydrochloric acid, ammonium persulfate.

INTRODUCTION

Desizing is the process of removing sizing materials (such as starch, CMC, or PVA) applied to cotton yarn (warp) prior to weaving process. This step is essential for improving fabric absorbency and preparing it for subsequent wet processing like scouring, bleaching, dyeing, or printing [1,2].
Common Desizing Methods include [3,4]:

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- Enzymatic Desizing - Uses amylase enzymes to hydrolyze starch-based sizing agents, making them water-soluble and easy to rinse.
- Acid Desizing - Employs dilute acids (usually sulfuric or hydrochloric) to hydrolyze the starch.
- Oxidative Desizing - Utilizes oxidizing agents like hydrogen peroxide to break down sizing material.
- Rot Steeping - Involves soaking fabric in water at moderate temperatures for extended periods, allowing microorganisms to degrade the starch - a slow and less common method today.

The changes in cotton fabric after desizing are as follows [5,6]:

1. Improved Absorbency - Starch removal opens up the cotton fibers. It facilitates better penetration of water, dyes, and chemicals, and is essential for even scouring, bleaching, and dyeing.
2. Surface Cleanliness - Sizing residue (e.g., starch, waxes, PVA) is eliminated. The fabric becomes cleaner and more hydrophilic. There is reduction in spotting, uneven dyeing, or print defects.
3. Softer Hand Feel - Desizing removes stiff sizing layers. Fabric becomes more flexible and pliable. This is especially noticeable after starch removal.
4. Slight Loss in Weight - Weight loss (typically 2–5%) is observed due to the removal of size material. This is useful for monitoring desizing efficiency.
5. Improved Uniformity in Downstream Processes - More consistent results in scouring, bleaching, and dye uptake are observed. This is critical for achieving level dyeing and bright shades.
6. Increased Porosity and Capillarity -Capillary action (wicking) is enhanced, which is important for functional finishes. This is especially relevant for technical textiles, sportswear, and medical fabrics.
7. Minimal Effect on Mechanical Strength (If properly done) - Enzymatic desizing is gentle and preserves fabric tensile strength. Acid or oxidative desizing can cause fiber degradation if misused.
8. Change in Surface Chemistry - Fabric surface becomes more reactive (by exposing hydroxyl groups on cellulose). This enhances chemical reactivity for bleaching, finishing, and dyeing.

Different desizing processes share the same objective - to break down starch into smaller water-soluble molecules. In the case of so-called synthetic sizing agents, warm water rinsing is generally sufficient for their removal due to their high water solubility. Natural sizing agents are somewhat more economical compared to synthetic ones, but are significantly more difficult to remove [7,8].

Starch removal from greige fabric is an important process because, in subsequent wet finishing treatments, the fabric needs to be easily and thoroughly wetted and dyed. Desizing is characteristic for cotton greige fabrics.

This research investigates various desizing processes for optimization purpose, including conventional chemical methods and eco-friendly enzymatic approaches using amylase as an environmentally sustainable alternative.

MATERIALS AND METHODS

The textile material used was a 100% greige cotton fabric with a starch-sized warp, a plain weave, the linear density of 30 tex for both warp and weft yarns, the thread density of 30 and 20 threads/cm for warp and weft, respectively, and the fabric mass per unit area of 175 g/m².

Recipe (per 100 dm^3 of sizing solution) for industrial sizing cotton warp (Karl Mayer Sizing Machine):

- Natural starch (corn): 5 kg.
- Soft water: up to 100 dm^3 (for solution preparation).
- Softening agent (Lurol-LA, Goulston Technologies): 0.2 kg.
- Antiseptic (sodium benzoate): 0.05 kg (to prevent fermentation).

Work procedure

The experimental laboratory work consisted of desizing cotton fabric using different methods. The treatments were carried out according to the procedures and formulations given in Table 1. After desizing, the fabric was thoroughly rinsed with warm and cold water, followed by air drying. All tests were conducted without conditioning the samples to standard moisture and temperature.

Table 1. Methods of Desizing of Cotton Fabric

Method designation (abbreviations)	Formulation for each method
HCl	Hydrochloric acid 2 g/dm^3, Avocet WET-N 1 g/dm^3, 1:20, 50 °C, 30 min; neutralize with sodium bicarbonate 1 g/dm^3
APS	Ammonium persulfate 3 g/dm^3, sodium carbonate 1,5 g/dm^3, Avocet WET-OX 1 g/dm^3, 1:20, 80 °C, 30 min; mild neutralization with acetic acid 0.5%
AMY	Termamyl Ultra 300L, 2 g/dm^3, Avocet WET-N 1 g/dm^3, pH 7, 1:20, 70 °C, 45 min; remove fabric, rinse thoroughly with warm water

Testing methods are as follows:

- Degree of desizing (based on mass changes).
- Water penetration absorption (SRPS F.S2.042:1985).
- Water absorption capacity (SRPS F.S2.041:1985).
- Breaking strength and elongation (SRPS EN ISO 13934-1:2015).
- Air permeability (SRPS EN ISO 9237:2010).

RESULTS AND DISCUSSION

Desizing of cotton fabric with warp yarns sized using a natural starch-based sizing agent was carried out using three methods, slightly modified from those commonly used in the industry. Each of these methods utilizes either conventional synthetic chemicals or natural-origin alternatives [7].

The desizing mechanism consists of converting water-insoluble amylose (linear α-1,4-linked glucose) and amylopectin (branched α-1,4 and α-1,6-linked glucose) into water-soluble products such as dextrin, maltose, or glucose.
Hydrochloric acid breaks down starch molecules (a polysaccharide) into smaller, soluble sugars through acid-catalyzed hydrolysis of the glycosidic bonds (α-1,4 and α-1,6 linkages) [9-11]:

$$(C_6H_{10}O_5)_n+nH_2O \xrightarrow{HCl} nC_6H_{12}O_6 \text{ (glucose)} \tag{1}$$

The reaction mechanism (1) with this acid is as follows:

1. Protonation: The glycosidic oxygen in the starch is protonated by H^+ from HCl.
2. Bond Cleavage: The protonated bond is cleaved, resulting in the formation of smaller dextrins and eventually glucose.
3. Solubilization: These products are water-soluble and can be rinsed.

Ammonium persulfate is a strong oxidizing agent. When dissolved in water and heated, it decomposes to form sulfate radicals ($SO_4^{\cdot -}$) and peroxodisulfate ions ($S_2O_8^{2-}$), which attack and break down the polysaccharide (starch) chains.
The key reactions are as follows [12,13]:

1. Decomposition (2,3):

$$(NH_4)_2S_2O_8 \rightarrow 2NH_4^{+}+S_2O_8^{2-} \tag{2}$$

$$S_2O_8^{2-}+H_2O \rightarrow SO_4^{\cdot -}+OH^{\cdot}+OH^{-} \text{ (upon heating or catalysis)} \tag{3}$$

2. Radical Attack: The sulfate radicals ($SO_4^{\cdot -}$) or hydroxyl radicals (OH) attack the C–C bonds and glycosidic linkages in starch molecules, resulting in fragmentation into lower molecular weight compounds like dextrins, aldehydes, and organic acids (4).

$$(C_6H_{10}O_5)_n+\frac{SO_4^{\cdot -}}{OH^{\cdot}} \rightarrow \text{Shorter dextrins} \rightarrow \text{Carboxylic acids}+CO_2 \tag{4}$$

3. Solubilization: These oxidation products are water-soluble and easily removed by rinsing.

Amylases are hydrolase enzymes that cleave the α-1,4-glycosidic bonds in starch. They act specifically on starch, without affecting cellulose (cotton fibers).
α-amylase randomly cleaves internal bonds, producing dextrins and maltose, while β-amylase cleaves from non-reducing ends, releasing maltose units [14-16] (5):

$$(C_6H_{10}O_5)n \text{ (starch)} + H_2O \rightarrow \text{dextrins + maltose + glucose} \tag{5}$$

The step-by-step mechanism is as follows:

1. Enzyme Binding: Amylase binds to the starch layer on the fabric surface.

2. Hydrolysis: It cleaves the α-1,4 bonds, reducing starch into water-soluble fragments (produces dextrins and oligosaccharides) (6).

$$(C_6H_{10}O_5)_n \xrightarrow{\alpha\text{-Amylase}} \text{Dextrins} \rightarrow \text{Maltose}(C_{12}H_{22}O_{11}) \rightarrow \text{Glicose}(C_6H_{12}O_6) \qquad (6)$$

3. Desorption: The solubilized sugars (maltose, glucose) are rinsed with water.

The first noticeable effect after various treatments in the desizing process of cotton fabric is the loss of mass due to starch degradation.

Mass loss refers to the reduction in dry weight of the fabric after desizing compared to its initial dry weight. It primarily reflects the removal of the sizing agents (e.g., starch) applied during weaving. However, with certain chemicals, it can also include loss of cellulose - which is undesirable.

Figure 1 presents the results of mass loss of cotton fabric samples depending on the active agent type, i.e., the desizing method employed. Desizing using thermostable amylase (AMY method) demonstrates optimal performance, achieving the highest starch removal efficiency of 7.5%.

The hydrochloric acid method (HCl method) gives relatively high mass loss, but may involve cellulose degradation with sizing material removal. Ammonium persulfate desizing (APS method) has a moderate weight loss, mainly due to starch oxidation, and there is also some fabric degradation. AMY gives the greatest controlled mass loss, effectively targeting starch, while preserving cellulose.

Mass loss is a reliable quantitative marker, but should always be interpreted alongside fabric integrity and performance in further processing.

Monitoring mass loss during desizing helps ensure the removal of sizing agents without damaging the fabric. Enzymatic desizing (AMY method) is the most controlled and sustainable method, while acid or oxidative agents require careful process control to avoid excessive loss.

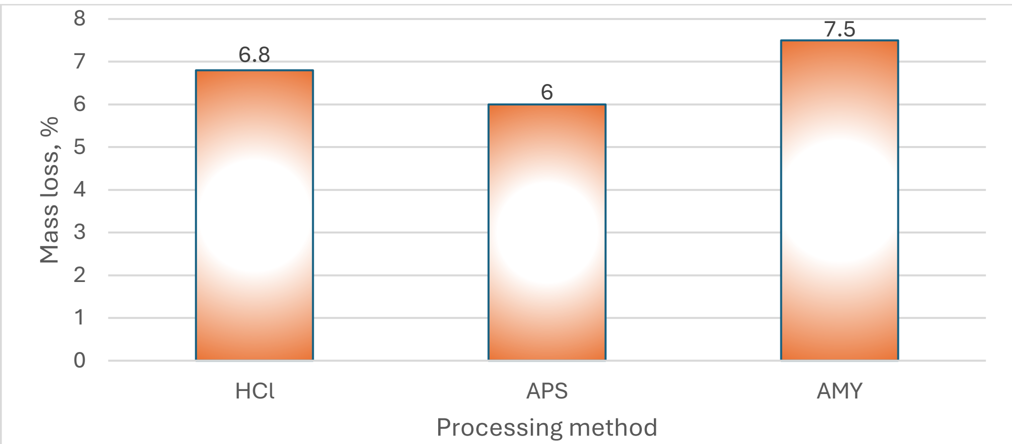

Figure 1. Mass loss of cotton fabric according to the applied desizing method

As a result of the removal of starch-based sizing agents from the fibers, an improvement in sorption properties occurs, along with enhanced surface appearance and hand feel. This is confirmed by fabric properties such as water penetration and absorption. The test results of these properties are presented in Figures 2 and 3.

Moisture absorption (or wetting ability) is a vital indicator of how well cotton fabric absorbs moisture - a property closely linked to desizing efficiency. After desizing cotton fabric using hydrochloric acid, ammonium persulfate, or thermostable amylase, moisture absorption performance reveals the extent of starch (hydrophobic sizing agent) removal and surface energy modification.

All specimens tested in the warp-direction exibited superior performance in this regard, which can be attributed to the higher thread density in the warp direction and consequently greater number of capillary pathways. The moisture absorption performance follows this descending order of desizing methods: AMY > APS > HCl > Greige sample. The AMY method demonstrates approximately ten times greater moisture absorption than the greige sample in both yarn directions.

Rapid moisture absorption after desizing confirms effective starch removal. Thermostable amylase offers the most uniform and safe improvement in moisture absorbency. Monitoring moisture absorption is a quick and practical method to assess desizing efficiency.

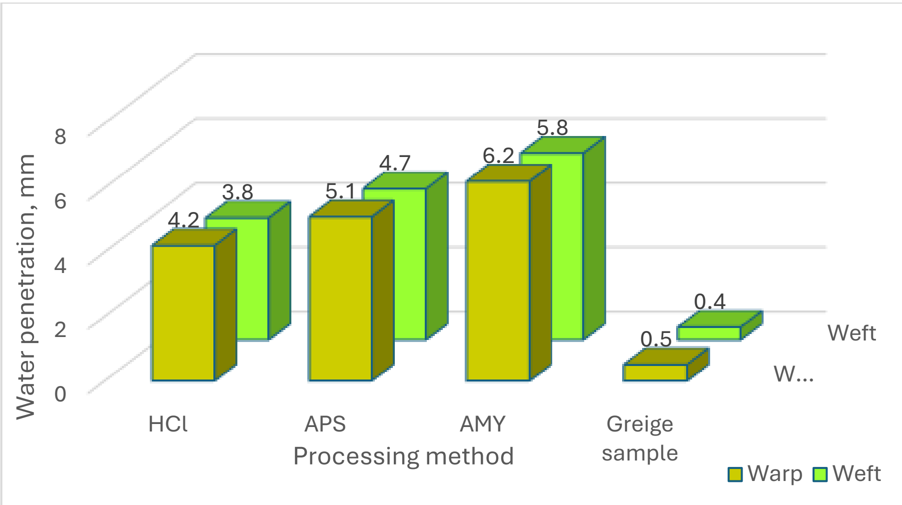

Figure 2. Moisture absorption – capillarity through cotton fabrics according to the applied desizing method

Water absorption is a critical parameter for evaluating the hydrophilicity of cotton fabric after desizing. It reflects how effectively the starch sizing agents have been removed from the fabric surface, allowing the cotton's natural water-absorbing properties to be restored. When desizing is carried out using HCl, APS, or AMY, each method influences water absorption differently, depending on its mechanism and impact on fiber integrity.

It can thus be concluded that all treatments yielded improved values for this parameter compared to the untreated sample. The best result was recorded with the AMY desizing method, which was approximately 4 times higher compared to the greige sample. The next closest result was observed in APY method, which was about 3 times higher in comparison to the greige sample.
The improvement of these sorption characteristics clearly indicates the success of the applied desizing methods, as they achieve a more open fabric structure accessible to the liquid medium. Cotton fibers and the fabric itself have an increased capacity to hold water on the surface and partially within the volumetric layers. This inherently means an enhancement of comfort and hygiene properties during practical use.
Thermostable amylase leads to the highest and most uniform water absorption, ideal for eco-friendly, high-quality processing. HCl can boost water absorption but at the risk of damaging fibers. APS offers a balance but must be optimized to prevent over-oxidation.

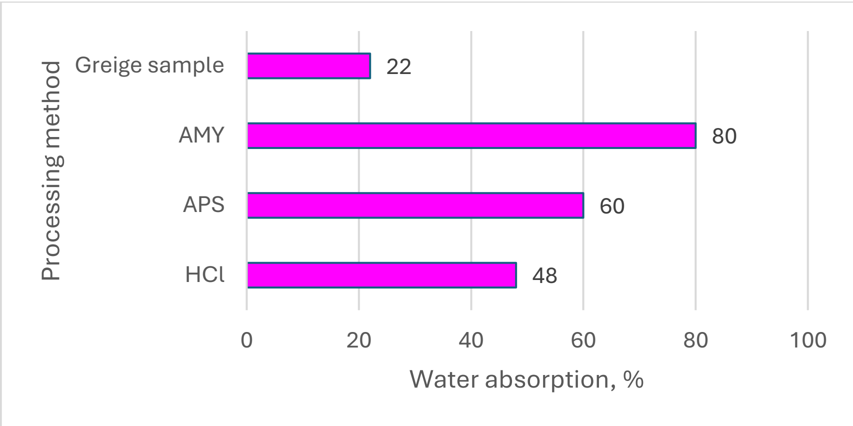

Figure 3. Water absorption of cotton fabric as a function of the applied desizing method

When discussing parameters that define the quality of a textile product, resistance to stress and deformation is particularly important, especially when expressed through breaking strength and elongation.
Breaking strength is a key parameter in evaluating the mechanical integrity of cotton fabric after desizing. When desizing is done using HCl, APS, or AMY, each agent affects the fabric differently – this is reflected in changes to the fabric's breaking strength. Elongation at break measures the extent to which a fabric can stretch before it breaks, and it is a crucial indicator of its flexibility and toughness. In the context of desizing cotton fabric, the choice of desizing agents can significantly impact elongation at break due to their varying effects on fiber integrity.
Figures 4 and 5 show the recorded results of these properties after desizing using different methods. All treatments resulted in lower values of breaking strength and elongation in both warp and weft directions. The greatest decrease in strength was observed with the HCl method, while the smallest decrease was recorded with the AMY method.

In the worst cases, the strength reduction (in the warp direction) amounted to around 19% compared to the value of the greige sample, which should not be a cause for concern. The presence of surfactants during desizing, in addition to improved wettability, contributed to reduced fiber surface damage by protecting the cotton fabric from excessive degradation. On the other hand, it is assumed that the presence of these substances in the desizing solution enables more uniform starch removal, thus allowing more favorable load distribution during tensile testing. The results for elongation at break closely followed the trend of breaking strength, showing a maximum reduction of up to 25%, regardless of the yarn direction. The enzyme Amylase (AMY) caused almost no damage to the fibers, as the results for these mechanical parameters di not significantly deviate from those of the greige sample.
Thermostable amylase is superior for preserving mechanical properties of cotton fabrics. Hydrochloric acid, though effective in removing starch, risks significant fiber damage, while ammonium persulfate offers a balance, but must be carefully controlled.

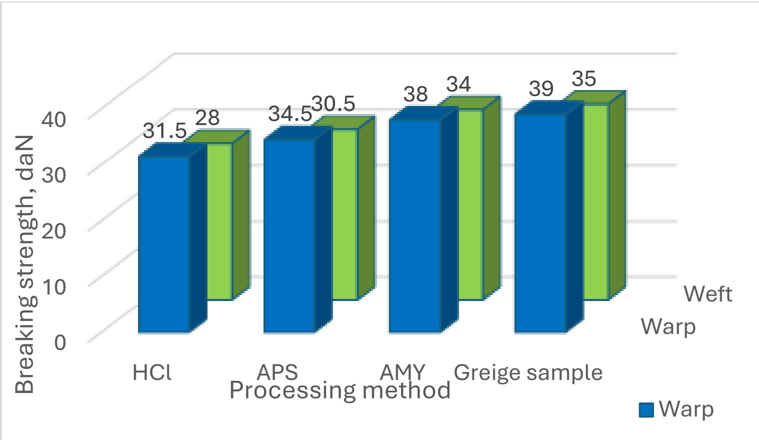

Figure 4. Breaking strength of cotton fabric according to the applied desizing method

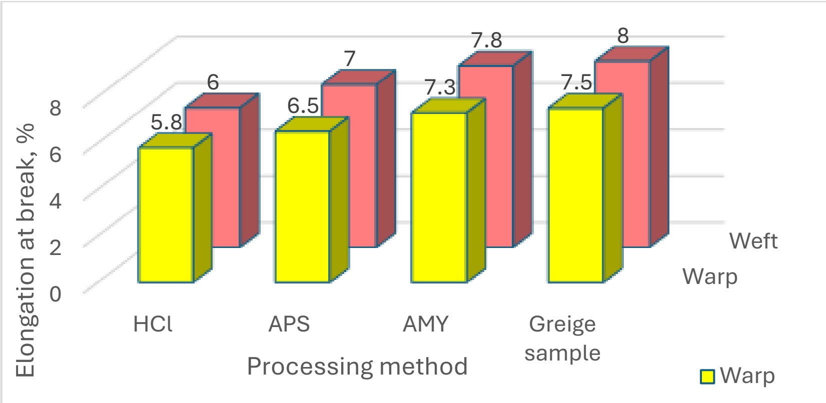

Figure 5. Elongation at break of cotton fabric according to the applied desizing method

Air permeability refers to the ability of air to pass through a fabric and is an important property for assessing breathability, comfort, and structure. During the desizing of the cotton fabric using hydrochloric acid, ammonium persulfate, or thermostable amylase, removal of starch and changes in fiber structure influence air permeability in different ways.

Air permeability of a textile product intended for clothing or other applications is a crucial indicator of the comfort and quality of fabrics. The discrete structure of fibrous constructions determines their porosity, which depends on the degree of compactness, i.e. density.

Figure 6 shows the results of air permeability testing of the fabric according to the desizing method. All treatments showed higher values for this parameter compared to the greige sample. This was expected, as air permeability is a measure of the total volume of free space between fibers, and since the fabric samples became 'freer' from starch after desizing, there was more void space available for air circulation.

The AMY method provided the highest air permeability values (100 $cm^3/cm^2/s$, compared to 30 $cm^3/cm^2/s$ for the greige sample), confirming the assumption that the fabric had been freed from starch, thus opening up pathways for unobstructed ventilation. This is of particular importance, especially if such fabric is intended for clothing production.

Thermostable amylase ensures clean starch removal and preserves weave structure, leading to high and consistent air permeability. Hydrochloric acid may increase permeability but risks structural inconsistency due to cellulose degradation. Ammonium persulfate offers a balanced improvement in permeability with moderate process impact.

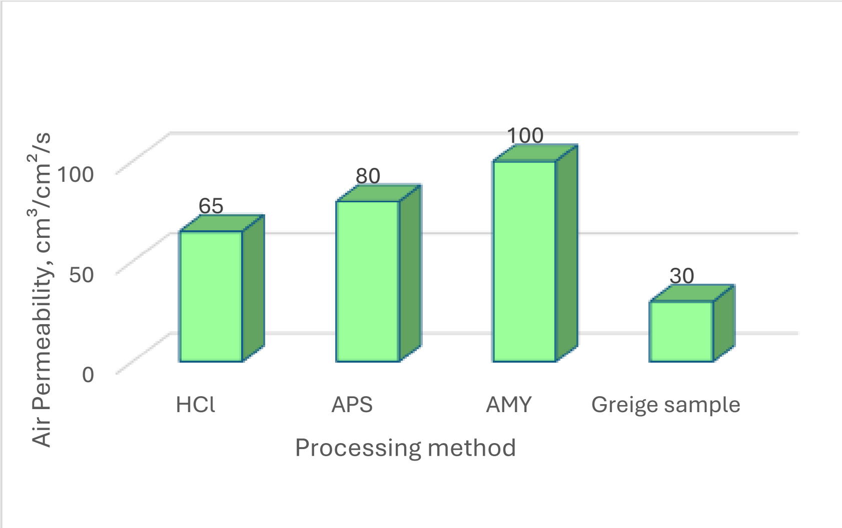

Figure 6. Air permeability of cotton fabric according to the applied desizing method

CONCLUSION

In the process of desizing of cotton fabric, starch undergoes hydrolysis and breaks down into lower molecular weight fractions that are water-soluble and can be easily removed from the fibers.

The study demonstrated that all three desizing methods–hydrochloric acid (HCl), ammonium persulfate (APS), and thermostable amylase (AMY)–effectively removed starch from cotton fabric. However, significant differences were observed in terms of fiber integrity, environmental impact, and post-desizing fabric performance. The enzymatic method using thermostable amylase proved to be the most effective and sustainable, achieving the highest desizing efficiency (up to 7.5% weight loss) with minimal damage to fiber structure. This method also resulted in superior improvements in sorption characteristics (water penetration and absorption), tensile strength retention, and air permeability, making it the most suitable for modern eco-friendly textile processing. In contrast, the acid-based method, while effective, caused notable fiber degradation and strength loss. APS showed intermediate performance, offering a balance between effectiveness and fiber preservation.

For sustainable textile processing, thermostable amylase is optimal when starch removal efficiency and fiber integrity are prioritized. APS may serve as a compromise for mixed sizing agents, whereas HCl should be limited to cost-driven applications accepting strength compromises. Future work should explore enzyme immobilization to enhance reusability.

Acknowledgment

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Izvod

EFIKASNOST ODSKROBLJAVANJA PAMUČNE TKANINE PRIMENOM RAZLIČITIH POSTUPAKA

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Odskrobljavanje pamučnih tkanina predstavlja ključnu fazu u procesu mokre obrade tekstila, koja direktno utiče na kasnije obrade i ukupne performanse tkanine. Ovo istraživanje istražuje efikasnost tri metode odskrobljavanja, koje za aktivne agense imaju: hlorovodoničnu kiselinu, amonijum-persulfat i termostabilnu amilazu. Efikasnost svake metode ocenjen je na osnovu sledećih parametara: promena mase tkanine, penetracija vode, kapacitet apsorpcije vode, čvrstoća na kidanje, izduženje pri kidanju i propustljivost vazduha. Rezultati daju jasne razlike u mehanizmima delovanja i efektima primenljivih sredstava za odskrobljavanja. Hlorovodonična kiselina i amonijum-persulfat su pokazali brzo uklanjanje sredstva za skrobljenje, ali su takođe izazvali primetno smanjenje mehaničkih svojstava i propustljivosti vazduha, što se pripisuje njihovom oksidacionom i kiselom dejstvu. Nasuprot tome, enzimsko odskrobljavanja upotrebom termostabilne amilaze omogućilo je efikasno uklanjanje sredstva za skrobljenje uz očuvanje čvrstoće, elastičnosti i propustljivosti tkanine. Ovi nalazi ukazuju na potencijal enzimskog odskrobljavanja kao prikladnije i ekološki prihvatljivije alternative u odnosu na konvencionalne hemijske metode, naročito za supstrat koji čini pamučna tkanina u platno prepletaju.

Ključne reči: pamučna tkanina, odskrobljavanje, amilaza, hlorovodonična kiselina, amonijum-persulfat.