TECHNICAL STUDY ON COLOR FASTNESS IN LEATHER DYEING

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Received: 03.02.2025 Accepted: 28.04.2025 https://doi.org/10.24264/lfj.25.2.1

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ABSTRACT. Through a systematic experimental study, this paper investigates the main factors affecting color stability in leather dyeing. Three sets of tests—water resistance, friction resistance, and acid-base resistance—were conducted using standard methods to evaluate leather color stability under different conditions. The results show that in the water resistance test (37 ± 2 °C), the specimens' color change rating reached Grades 4-5, and the staining rating on the multifiber adjacent fabric ranged from Grades 3-4 to 4. In the friction resistance test, under dry friction conditions, both the color change rating of the specimens and the staining rating of the friction cloth reached Grade 5, whereas under wet friction conditions, the staining rating of the friction cloth fell to Grade 3. In the acid-base resistance test, acidic solutions exerted the greatest impact on color stability, while alkaline solutions primarily caused physical changes on the leather surface. These findings provide a theoretical basis and technical support for improving color stability in leather dyeing processes.

KEYWORDS: leather dyeing, color stability, water resistance, friction resistance, acid-base resistance

STUDIU TEHNIC PRIVIND REZISTENȚA CULORII LA VOPSIREA PIELII

REZUMAT. Acest studiu analizează, printr-o cercetare experimentală sistematică, principalii factori care influențează stabilitatea culorii la vopsirea pielii. S-au efectuat trei seturi de teste privind rezistența la apă, rezistența la frecare și rezistența la acizi și baze, folosind metode standard pentru a evalua stabilitatea culorii pielii în diferite condiții. Rezultatele arată că, în urma testului de rezistență la apă (37 ± 2 °C), gradul de decolorare al eșantioanelor a atins nivelul 4-5, iar gradul de pătare pe țesătura multifibră s-a situat între 3-4 și 4. În urma testului de rezistență la frecare, în condiții de frecare uscată, atât gradul de decolorare al probelor, cât și gradul de pătare al materialului de fricțiune au atins nivelul 5, în timp ce, în condiții de frecare umedă, gradul de pătare al materialului de fricțiune a scăzut la nivelul 3. În urma testului de rezistență la acizi și baze, soluțiile acide au avut cel mai mare impact asupra stabilității culorii, în timp ce soluțiile alcaline au provocat în principal modificări fizice la suprafața pielii. Aceste concluzii oferă o bază teoretică și suport tehnic pentru îmbunătățirea stabilității culorii în procesul de vopsire a pielii.

CUVINTE CHEIE: vopsirea pielii, stabilitatea culorii, rezistența la apă, rezistența la frecare, rezistența la acizi și baze

ÉTUDE TECHNIQUE SUR LA SOLIDITÉ DE LA COULEUR DANS LA TEINTURE DU CUIR

RÉSUMÉ. Grâce à une étude expérimentale systématique, cet article examine les principaux facteurs influençant la stabilité de la couleur lors de la teinture du cuir. Trois séries de tests — la résistance à l'eau, la résistance au frottement et la résistance aux acides et aux bases — ont été menées à l'aide de méthodes standard afin d'évaluer la stabilité de la couleur du cuir dans différentes conditions. Les résultats expérimentaux montrent que, lors du test de résistance à l'eau (37 ± 2 °C), le degré de décoloration des échantillons a atteint les niveaux 4-5, tandis que le degré de coloration sur le tissu multifibre se situe entre 3-4 et 4. Lors du test de résistance au frottement, en condition de frottement à sec, le degré de décoloration des échantillons et le degré de coloration du tissu de frottement ont tous deux atteint le niveau 5, alors qu'en condition de frottement humide, le degré de coloration du tissu de frottement est tombé au niveau 3. Pour le test de résistance aux acides et aux bases, les solutions acides ont eu l'impact le plus important sur la stabilité de la couleur, tandis que les solutions alcalines ont principalement provoqué des modifications physiques à la surface du cuir. Ces résultats fournissent une base théorique et un soutien technique pour améliorer la stabilité de la couleur dans le processus de teinture du cuir.

MOTS CLÉS : teinture du cuir, stabilité de la couleur, résistance à l'eau, résistance au frottement, résistance aux acides et aux bases

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INTRODUCTION

Leather dyeing is a critical step in leather processing and manufacturing, and its color stability directly affects product appearance, service life, and market competitiveness [1]. In recent years, as consumers demand higher-quality leather products and environmental awareness increases, developing dyeing processes with high color stability and environmental friendliness has become a key research focus in the industry [2].

However, many issues are encountered in the practical application of traditional leather dyeing techniques, such as insufficient color fastness, uneven dyeing, and chemical dye pollution [3]. Scholars both domestically and internationally have conducted extensive research to tackle these problems. Studies indicate that the color stability of leather dyeing is influenced by multiple factors, including the nature of the dyes, dyeing process parameters (pH, temperature, concentration, time, etc.), and the coordination of preceding and subsequent processes [4-7].

Leather dyeing is a complex physicochemical process involving the adsorption, diffusion, and fixation of dye onto the leather surface from the dye bath. This process is closely related to factors such as the type of dye, the type of leather, and the degree of leather neutralization [8]. Key indicators for evaluating leather quality include dry and wet rub fastness, water fastness, and acid-base color fastness [9]. Specifically, rub fastness tests assess color transfer by simulating friction; water fastness tests evaluate color change and staining by soaking the leather in distilled water; and acid-base tests involve treating the leather with solutions of different pH values to determine color fastness [7, 10-12].

In this study, a systematic experimental design was employed to examine how temperature, pH, friction conditions, and other factors affect color stability in leather dyeing, with the goal of providing both theoretical underpinning and technical support for improving dyeing processes. The findings of this research will not only offer technical guidance for the leather industry but also serve as a reference for related fields.

EXPERIMENTAL

Materials and Methods

Experimental Materials

(1) Leather Samples

A total of eleven standardized vegetable-tanned leather samples were utilized in this study. These samples were sourced from the same production batch to ensure consistency in tanning and finishing processes. They were randomly assigned into three test groups based on the specific color fastness tests:

- Water Resistance Test Group: 3 samples (coded W1, W2, W3);
- Friction Resistance Test Group: 4 samples (coded F1, F2, F3, F4);
- Acid and Alkali Resistance Test Group: 4 samples (coded A1, A2, A3, A4).

Each leather specimen was cut into dimensions of 10 cm × 10 cm and conditioned in a standard atmosphere (20 ± 2 °C and 65 ± 4% RH) for at least 24 hours prior to testing, according to ISO 2419:2012 for leather sample preparation.

(2) Auxiliary Materials

Multifiber Adjacent Fabric: A standardized multifiber fabric (ISO 105-F10) consisting of wool, polyamide, acrylic, cotton, polyester, and acetate fibers was used to evaluate staining during water fastness tests.

Standard Friction Cloths: White cotton test cloths conforming to ISO 105-X12 were used in both dry and wet friction tests to assess dye transfer.

(3) Chemical Reagents

All chemical reagents were of analytical grade and used without further purification. The following solutions were prepared for acid and alkali resistance testing:

- Ammonium hydroxide solution: 1.0 mol/L;
- Sodium carbonate solution: 0.1 mol/L;

- Calcium hydroxide solution: saturated solution;
- Hydrochloric acid solution: 0.1 mol/L.

All solutions were freshly prepared using deionized water prior to testing to ensure consistency and accuracy in pH levels.

Test Methods

(1) Water Fastness Test

The objective was to evaluate the resistance of leather samples to color change and staining when exposed to water under controlled conditions.

Each leather sample (W1–W3) was cut into a 10 cm × 4 cm strip. A piece of multifiber adjacent fabric (same size) was sewn tightly onto the test sample using cotton thread, ensuring full surface contact. The combined specimen was fully immersed in distilled water preheated to 37 ± 2 °C for 30 minutes. After immersion, the specimen was removed and placed between two glass plates with a 500 g weight to prevent curling. Drying was conducted in a climate-controlled chamber at 20 ± 2 °C and 65 ± 4% RH for 24 hours.

Color change on the leather surface and staining on the multifiber adjacent fabric were assessed under a D65 standard light source using ISO 105-A03 (Gray Scale for Color Change) and ISO 105-A04 (Gray Scale for Staining). Ratings were assigned from Grade 1 (poor) to Grade 5 (excellent), independently by two trained evaluators.

(2) Friction Fastness Test

The objective was to assess the color transfer and durability of dye under dry and wet friction conditions.

Each leather sample (F1–F4) was mounted securely on the base of a Crockmeter (ISO 105-X12). For dry friction, a standard white cotton test cloth was rubbed against the leather surface under a fixed load of 9 N for 10 cycles (one cycle = one forward and one backward motion). For wet friction, the cotton cloth was moistened with distilled water (soaked and squeezed to 100% pick-up by weight), then used in the same manner.

The degree of staining on the test cloth was rated using ISO 105-A04. The color change of the leather was also visually assessed using ISO 105-A03. Testing was conducted under a D65 light source, and the ambient humidity was controlled at 65 ± 4% RH.

(3) Acid and Alkali Resistance Test

The objective was to examine the effect of acidic and alkaline environments on leather color stability and surface integrity.

Leather samples (A1–A4) were immersed individually in 100 mL of each prepared solution (see Section 1.3) for 15 minutes at room temperature (23 ± 2 °C). Following immersion, the samples were blotted dry using filter paper and then air-dried under standard atmospheric conditions (20 ± 2 °C, 65 ± 4% RH) for 24 hours.

Color changes were evaluated using ISO 105-A03 gray scale. Surface alterations (e.g., hardening, spotting, swelling) were recorded through visual inspection and photographic documentation, using a magnifying lens (10×) where necessary to identify micro-defects. All observations were made under a D65 light source to standardize visual assessment.

Evaluation Criteria

(1) Color Fastness Rating Standards

Color fastness was assessed in accordance with internationally recognized ISO standards to ensure the accuracy and reproducibility of results. Two aspects were evaluated:

- Color Change of Leather Samples: Evaluated using ISO 105-A03 (Gray Scale for Assessing Change in Color), which consists of pairs of gray chips rated from Grade 5 (no change) to Grade 1 (very severe change);
- Staining of Adjacent or Friction Fabrics: Evaluated using ISO 105-A04 (Gray Scale for Assessing Staining), also rated from Grade 5 (no staining) to Grade 1 (heavy staining).

Each sample was rated independently by two trained evaluators under a D65 standard light source in a viewing cabinet compliant with ISO 3664:2009. If any discrepancy occurred, a third evaluator was consulted to reach consensus.

(2) Surface Change Evaluation

For acid and alkali resistance tests, physical surface changes of leather samples were assessed through:

- Visual Inspection: Identification of visible alterations such as discoloration, hardening, roughening, blistering, or spot formation;
- Magnification: When necessary, a 10× magnifying lens was used to detect microstructural damage or residue on the surface;
- Photographic Documentation: Before-and-after images were captured under standardized lighting to support qualitative comparison and reproducibility.

Descriptive terms (e.g., "no change", "surface hardened", "spot formation") were used in conjunction with color ratings to provide a more holistic evaluation of chemical resistance.

(3) Data Analysis and Visualization

All color fastness ratings were compiled in structured data tables and averaged where appropriate. To facilitate interpretation and comparison:

- Results were visualized using bar charts and line graphs generated with Microsoft Excel and OriginPro 2023;
- Standard deviation was calculated for each test group to assess the variability of performance across samples;
- Observed trends (e.g., higher color change in acidic environments or lower staining under dry friction) were cross-analyzed with sample composition and testing conditions.

RESULTS AND DISCUSSIONS

Water Resistance Test

The results of the water resistance test (Table 1) indicated that leather samples W1-W3 achieved color change ratings of Grade 4-5, and the staining ratings on multifiber adjacent fabrics ranged from Grade 3-4 to 4. These results demonstrate strong resistance to water-induced dye migration, suggesting good fixation of dyes under wet conditions at 37 ± 2 °C. This is consistent with previous findings indicating that thermal conditions close to human body temperature optimize dye diffusion and fixation due to balanced molecular mobility [4].

In particular, the slightly lower staining ratings for polyamide and polyester fibers (Grade 3-4) imply a material-dependent dye transfer phenomenon, possibly due to the structural and polarity differences among fibers [9]. This observation aligns with Wen *et al.*, who noted that synthetic fibers tend to exhibit higher dye absorption when tested under aqueous conditions [6]. These results suggest that evaluating leather color fastness should account for the interaction between dye molecules and adjacent textile fibers.

Table 1: Water Resistance Color Fastness Test for Leather

	Sample	Wool	Polyamide	Acrylic	Cotton	Polyester	Acetate
Before Immersion	4-5	4	3-4	4	4	3-4	4
After Immersion	4-5	4	3-4	4	4	4	4

Friction Resistance Test

Under dry friction conditions, all tested leather samples and friction cloths achieved a rating of Grade 5, indicating excellent color retention and minimal staining. This performance reflects efficient dye fixation on the leather surface, in line with industry standards for high-quality leather products [11]. However, under wet friction conditions, although the samples still maintained high color change ratings (Grade 5), the staining ratings of the rubbing cloths dropped to Grade 3, suggesting increased dye transfer in the presence of moisture (Table 2).

This decline in performance under wet conditions corroborates earlier studies by Yin *et al.*, which identified water as a plasticizing agent that increases dye mobility on the substrate surface [7]. The difference in performance between dry and wet conditions emphasizes the importance of moisture control in end-use scenarios. It also points to a need for improved water-resistant coatings or dye formulations to minimize transfer in humid environments [10].

Table 2: Friction Resistance Color Fastness Test for Leather

	Dry Friction		Wet Friction	
	Sample	Dry Friction cloth	Sample	Wet Friction cloth
Before Friction	5	5	5	5
After Friction	5	5	5	3

Acid and Alkali Resistance Test

The color change ratings and observed surface conditions revealed varied effects based on the solution's pH (Table 3). Hydrochloric acid (pH ≈ 1) caused the most severe color change (Grade 5) with no visible surface damage, suggesting strong chemical interaction between acidic media and dye molecular structures. This supports the findings of Zhang *et al.*, who reported that acidic environments can disrupt dye-fiber bonds, leading to substantial color alterations [1].

Conversely, exposure to ammonium hydroxide and calcium hydroxide (alkaline media) caused minimal color change (Grades 1-3) but led to visible surface hardening or spot formation. These results suggest that alkaline conditions affect the physical properties of the leather rather than the chromophores themselves, a mechanism highlighted in the work of [4].

Table 3: Acid and Alkali Resistance Test for Leather

Solution	Color Change Rating	Surface Changes
Ammonium Hydroxide	1	Surface Hardened
Sodium Carbonate	2-3	No Change
Calcium Hydroxide	2-3	Spot Formation
Hydrochloric Acid	5	No Change

Summary and Practical Implications

Overall, the data indicate that:

Water and wet friction conditions present the most significant challenges for maintaining color stability, due to increased dye mobility.

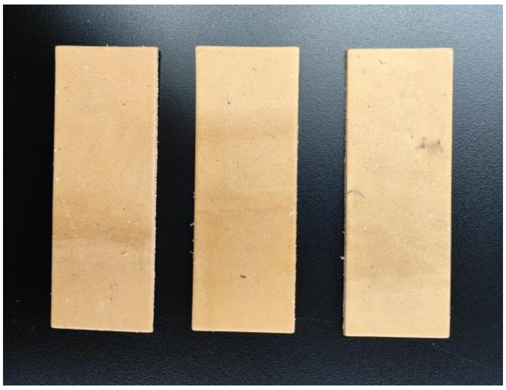
Acidic environments cause substantial chemical changes in dye structures, while alkaline solutions induce physical alterations on the leather surface.

The interaction between dye, leather matrix, and external stimuli (moisture, pH, friction) must be comprehensively evaluated in fastness testing, as supported by recent literature [7, 9].

These findings provide valuable insights for optimizing dye selection, dyeing parameters, and post-treatment processes, especially in applications where leather is exposed to dynamic environmental conditions.

ANALYSIS OF RESULTS

Based on the water resistance test results, a detailed analysis was conducted on factors affecting color stability. The test temperature of 37 ± 2°C indicates that temperature has a certain influence on color stability. Variations in temperature may lead to the diffusion or migration of dye molecules within the leather, thereby affecting color stability. The light source used in the experiments was D65, which simulates daylight. Different light sources can cause variations in the visual appearance of color, thus influencing color stability. Regarding the color change ratings, the test results show that Samples W1, W2, and W3 all achieved ratings of 4-5, indicating that under the experimental conditions, the leather exhibits relatively high color stability. The results further reveal that the staining ratings for wool, acrylic, cotton, and acetate fibers were all Grade 4, whereas polyamide and polyester fibers received ratings of 3-4. This suggests that the lower staining ratings of polyamide and polyester fibers may negatively affect overall color stability. Key factors influencing color stability include temperature, the light source used for observation, the color change rating of the samples, and the staining rating on the multi-fiber adjacent fabric. In practical applications, it is necessary to consider these factors comprehensively in order to ensure the color stability of leather.



Before the Experiment

After the Experiment

Figure 1. Comparison Before and After the Experiment

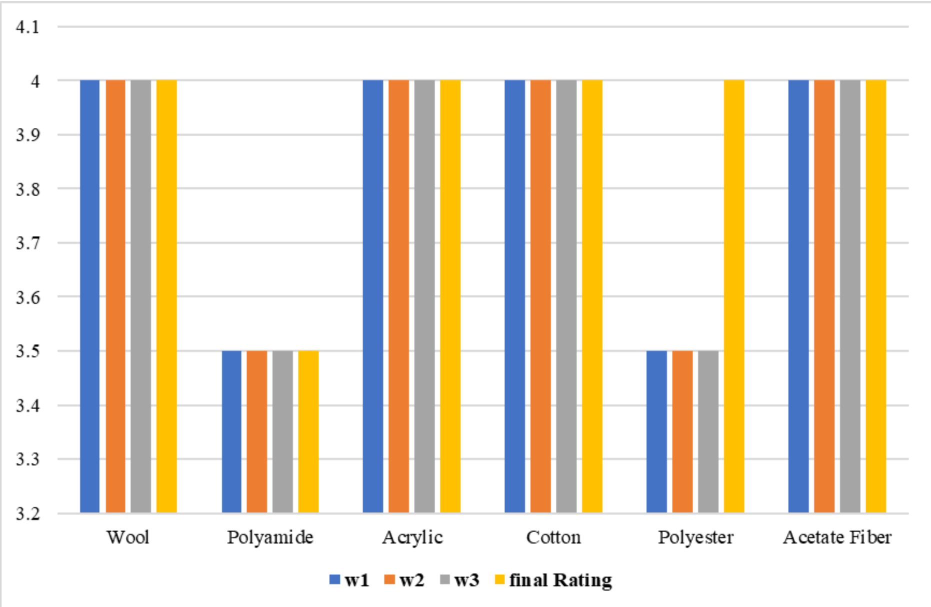


Figure 2. Figure of Color Change Ratings for Different Fiber Types

Based on the results of the friction resistance test, the color change grades for F1 and F2 under dry friction testing are both 5, indicating excellent color stability under dry friction conditions with no noticeable discoloration. The staining grades for Rubbing Cloth 1 and Rubbing Cloth 2 are also both 5, showing that under dry friction conditions, these rubbing cloths also exhibit excellent color stability with no significant staining.

Under wet friction testing, the color change grades for F3 and F4 are both 5, demonstrating that these samples maintain excellent color stability under wet friction conditions with no obvious discoloration. However, the staining grades for Rubbing Cloth 3 and Rubbing Cloth 4 are both 3, indicating that under wet friction conditions, the color stability of these rubbing cloths is relatively poor, with noticeable staining.

The main factors affecting color stability are as follows. In terms of friction conditions, under dry friction conditions, both the samples and the rubbing cloths exhibit excellent color stability, with no significant discoloration or staining. However, under wet friction conditions, while the samples still maintain excellent color stability, the color stability of the rubbing cloths significantly decreases, resulting in noticeable staining. This shows that wet friction conditions have a significant impact on the color stability of the rubbing cloths.

Table 4: Changes Before and After Sample Testing

	Before Testing	After Testing
Dry Friction		
Wet Friction		

In terms of material composition, the excellent color stability of F1, F2, F3, and F4 indicates that the materials of these samples provide good protection for color stability. Rubbing Cloth 1 and Rubbing Cloth 2 demonstrate good color stability under dry friction conditions, but the color stability of Rubbing Cloth 3 and Rubbing Cloth 4 significantly decreases under wet friction conditions. This suggests that the materials of the rubbing cloths are more prone to being affected by wet friction conditions.

Wet friction significantly affects dye transfer, as evidenced by higher staining ratings, underscoring the importance of material selection in moist environments.

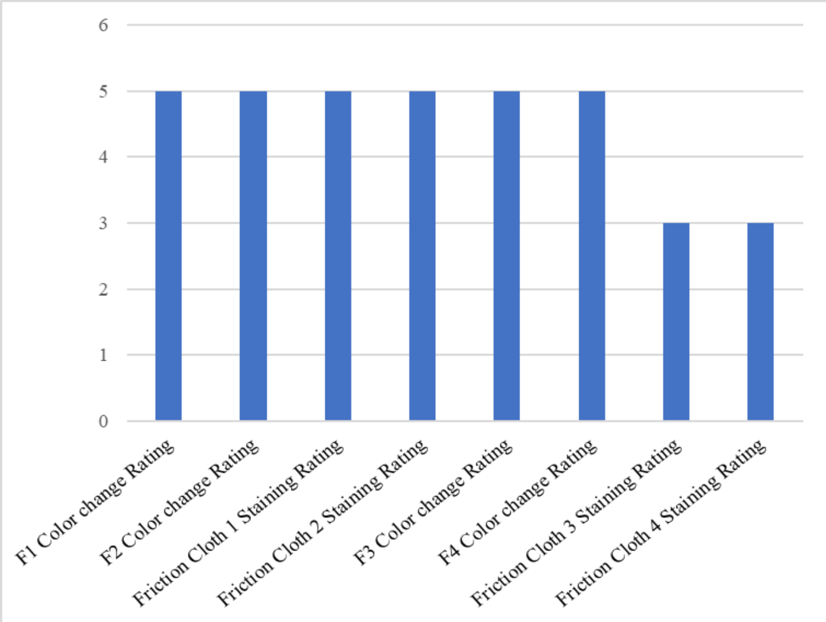


Figure 3. Leather Friction Resistance Color Fastness Grade Chart

Based on the experimental data table on the acid and alkali resistance of leather, we can analyze the factors affecting the color stability of leather. One of the factors is the observation light source. In the experiment, a D65 light source was used, which is a standard light source designed to simulate natural daylight. The choice of light source is crucial for observing and evaluating color, but in this experiment, the light source was fixed and therefore did not affect color stability.

The experiment involved four different solutions: ammonium hydroxide, sodium carbonate, calcium hydroxide, and hydrochloric acid. These solutions have different pH levels. Ammonium hydroxide and calcium hydroxide are alkaline solutions, sodium carbonate is a weakly alkaline solution, and hydrochloric acid is an acidic solution.

The color change grade is an indicator used to measure the degree of color change. The higher the grade, the more significant the color change. The surface changes describe the physical changes observed on the leather surface in different solutions.

Color Change Analysis Results

Ammonium Hydroxide: The color change grade is 1, and the surface becomes harder. This indicates that in an alkaline solution, the color change of the leather is minimal, but physical changes occur on the surface.

Sodium Carbonate: The color change grade is 2-3, with no surface changes. This shows that in a weakly alkaline solution, the leather experiences moderate color changes, but the surface remains unaffected.

Calcium Hydroxide: The color change grade is 2-3, with spots appearing on the surface. This indicates that in an alkaline solution, the leather shows moderate color changes, but spots appear on the surface.

Hydrochloric Acid: The color change grade is 5, with no surface changes. This demonstrates that in an acidic solution, the leather undergoes the most significant color change, but the surface remains unaffected.

In conclusion, acidic and alkaline environments impact both the color and physical stability of dyed leather. These effects should be carefully considered during process optimization.

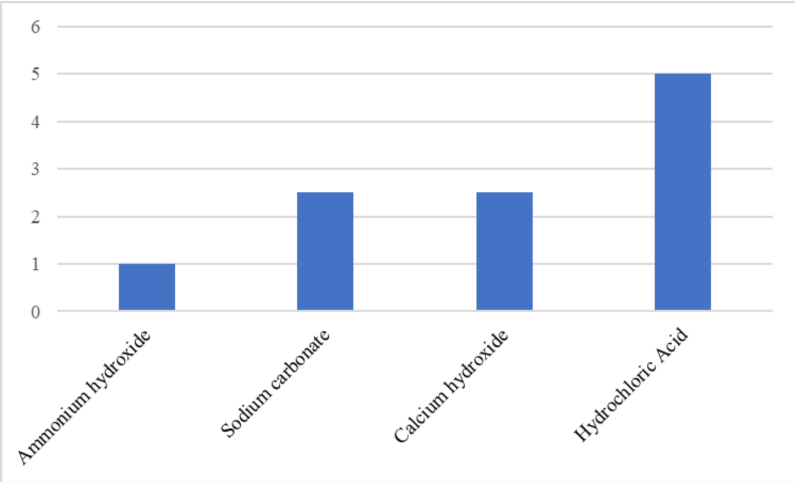


Figure 4. The Impact of Different Solutions on the Color Change Grade of Leather

Analysis of the Effects of Different Dyeing Processes and Post-Treatment Techniques on Color Stability

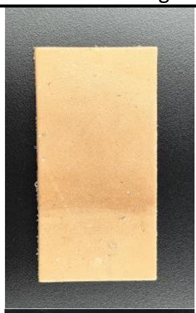
(1) Impact of Acidity and Alkalinity on Color Stability: Acidic solutions (e.g., hydrochloric acid) have the greatest impact on the color stability of leather, resulting in the most noticeable color changes. Alkaline solutions (e.g., ammonium hydroxide, calcium hydroxide) and weakly alkaline solutions (e.g., sodium carbonate) have a smaller impact on color stability.

(2) Surface Changes: Alkaline solutions can cause physical changes to the leather surface, such as hardening and the appearance of spots. While acidic solutions have the greatest impact on color, they do not cause significant physical changes to the surface.

(3) Color Stability: The color stability of leather is primarily influenced by the acidity and alkalinity of the solution, with acidic solutions having the most significant impact. Alkaline solutions may also lead to physical changes on the leather surface.

Table 5: Changes in Leather Before and After Testing with Different Solutions

	Before Testing	After Testing
Ammonium Hydroxide		
Sodium Carbonate		

	Before Testing	After Testing
Calcium Hydroxide		
Hydrochloric Acid		

RESULTS AND DISCUSSION

This study, through systematic experimental design, reveals the key factors affecting the color stability of leather dyeing and their mechanisms of action.

In terms of temperature effects, 37 ± 2 °C has been proven to be the optimal testing temperature, as it closely resembles the normal usage environment of human skin. At this temperature, the dye molecules and leather fibers maintain a stable bond, avoiding the breaking of bonds due to excessively high temperatures or the hindered diffusion and fixation of dyes caused by excessively low temperatures. This finding provides important guidance for optimizing dyeing processes.

The effect of pH on the color stability of leather exhibits a clear pattern. Acidic environments primarily impact color stability by damaging the molecular structure of the dyes, while alkaline environments affect overall performance by altering the physical properties of the leather surface. These differential effects suggest that strict control of pH during the dyeing process is essential in practical production. It is recommended to maintain the pH in the range of 6.5-7.5 to ensure maximum stability in dyeing results. Moreover, this provides direction for developing new protective treatment processes, such as creating a pH buffering layer on the leather surface to improve its adaptability in varying environments.

The study on friction conditions highlights the significant impact of moisture on dyeing stability. The excellent performance under dry friction conditions demonstrates that current dyeing processes have achieved good results in dye fixation. However, the significant performance decline under wet friction conditions indicates that improving the dyeing stability of leather in humid environments remains a technical challenge. Potential solutions include modifying dye molecular structures to enhance water resistance or developing new surface waterproof treatment technologies.

Compared to existing studies, the innovation of this research lies in systematically investigating multiple influencing factors and quantitatively analyzing their interrelationships. The experimental results not only validate existing theoretical understandings but also uncover new phenomena, such as the specific impact of alkaline solutions on the surface structure of leather. These findings offer new insights for further optimizing dyeing processes.

CONCLUSIONS

Through a systematic study of the issue of color stability in leather dyeing, this research has led to the following main conclusions:

First, temperature, pH, and friction conditions are the key factors affecting the color stability of leather dyeing. Among them, 37 ± 2 °C is identified as the optimal testing temperature, and the pH should be controlled within the range of 6.5-7.5. Second, humidity is a critical factor influencing dye migration, and special protective measures are required under humid conditions. Third, solutions with different pH values affect leather through distinct mechanisms: acidic solutions primarily impact the molecular structure of dyes, while alkaline solutions lead to changes in the physical properties of the leather surface.

Based on the research findings, the following recommendations are made for practical production: strictly control dyeing process parameters, particularly temperature and pH; improve dye fixation techniques to enhance water resistance; and develop innovative surface protection methods to improve the adaptability of leather in various environments.

Future research directions include the development of new environmentally friendly dyes, the study of intelligent control technologies, and the establishment of predictive models for color stability. With technological advancements, green dyeing processes, intelligent manufacturing technologies, and personalized customization solutions are expected to become the main trends in industry development.

Acknowledgements

This paper acknowledges the support of the 2024 Provincial-Level University Student Innovation and Entrepreneurship Training Program Project, “Color Leather Craft Dyeing – Creating a Leather Paste Dyeing Art Experience Center” (S202413418002S).

REFERENCES

1. Zhang, H.M., Xu, K., Dyes and Pigments for Leather Coloring, *Dyes and Dyeing*, **2021**, 4, 17-32.
2. Mi, L.F., Tong, C.B., Analysis of Application Directions and Development Trends of Leather Chemical Materials, *Chemical Fiber and Textile Technology*, **2022**, 12, 15-17, https://doi.org/10.3969/j.issn.1672-500X.2022.12.005.
3. Zhang, W.B., Zhang, H., Ma, J.Z., Tian, Z.H., Wei, L.F., Pan, C.Y., Zhang, W.B., Zhang, H., Ma, J.Z., Tian, Z.H., Wei, L.F., Pan, C.Y., Research Progress on Methods and Technologies for Improving Leather Dyeing Performance, *Fine Chemicals*, **2023**, 3, 521-531, https://doi.org/10.13550/j.jxhg.20220486.
4. Zhang, H.M., Xu, K.K., Leather Dyeing Immersion Process, *Dyes and Dyeing*, **2022**, 2, 34-43.
5. He, Z.G., Ran, S.Y., Zhou, A.H., Wu, Y.Y., Yang, L.M., Preliminary Study on Crossover Design Application of Leather Installation Art: Embroidery Red Flag, *Leather Science and Engineering*, **2024**, 5, 116-124, https://doi.org/10.19677/j.issn.1004-7964.2024.05.016.
6. Wen, S., Wang, L., Wan, H., Precautions in the Detection Process of Textile Splicing and Mutual Dyeing Fastness, *Textile Report*, **2024**, 8, 1-3, https://doi.org/10.3969/j.issn.1005-6289.2024.08.002.
7. Yin, C.L., Liu, L.L., Zhang, W.W., Sun, Y.X., Relevant Discussions on Colorfastness Testing of Textiles, *Chemical Fiber and Textile Technology*, **2024**, 9, 93-96, https://doi.org/10.3969/j.issn.1672-500X.2024.09.029.
8. Zhang, J.B., Wen, B.T., Wu, F., Ning, H., Study on the Dyeing Performance of Reactive Dyes, *Dyeing and Finishing Technology*, **2024**, 10, 28-31, https://doi.org/10.3969/j.issn.1005-9350.2024.10.006.
9. Cao, J.L., Xu, Z.Q., Jin, Y.H., Zhang, Y.H., Sun, X., Zha, J.D., Analysis on Current Testing Methods for Color Fastness of Leather, *Beijing Leather*, **2023**, 12, 48-53.
10. Ma, H.L., Cheng, X., Development and Application of Textile Colorfastness Testing Technology, *Cotton Science,* **2024**, 4, 134-136, https://doi.org/10.3969/j.issn.2095-3143.2024.04.051.
11. Wang, W.D., Liu, T., Zheng, Y.Y., Ding, A.B., Review of Standard Methods for Testing

Rubbing Fastness of Textiles, *Textile Standards and Quality*, **2023**, 4, 12-16.

12. Zhang, Y., Zhang, L.L., Wang, Q., Wang, D.L., Zhou, L.J., Comparative Analysis of Different Types of Linings in the Color Fastness Test, *Tianjin Textile Science & Technology*, **2021**, 4, 36-39, https://doi.org/10.13518/j.cnki.tjtst.2021.04.010.