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TECHNICAL STUDY ON COLOR FASTNESS IN LEATHER DYEING

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.

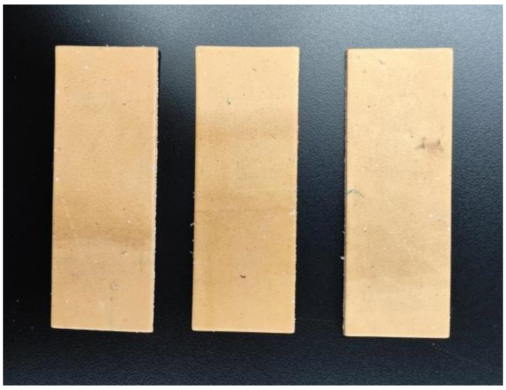
Acidic environments cause substantial chemical changes in dye structures, while alkaline solutions induce physical alterations on the leather surface.

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

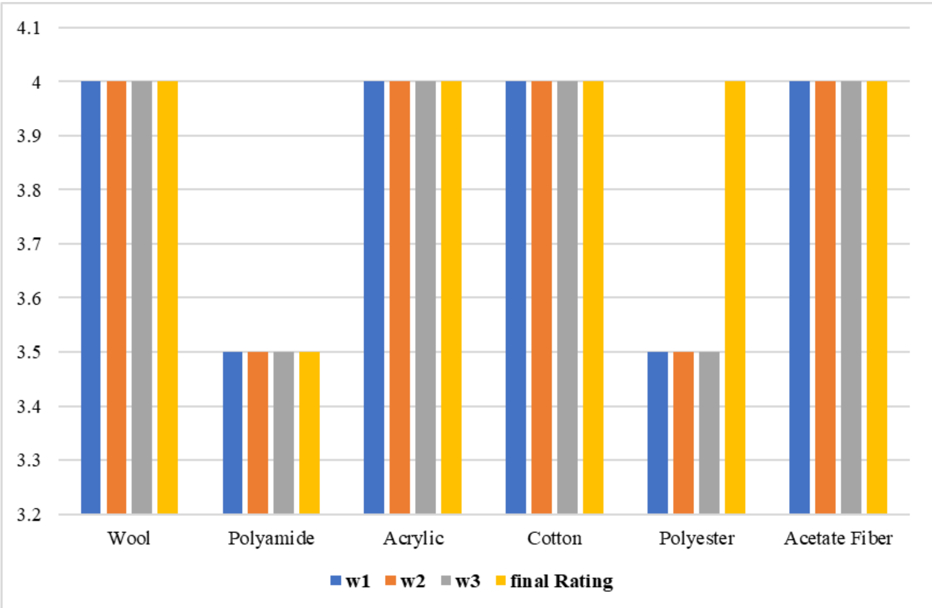


Figure 2. Figure of Color Change Ratings for Different Fiber Types

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.

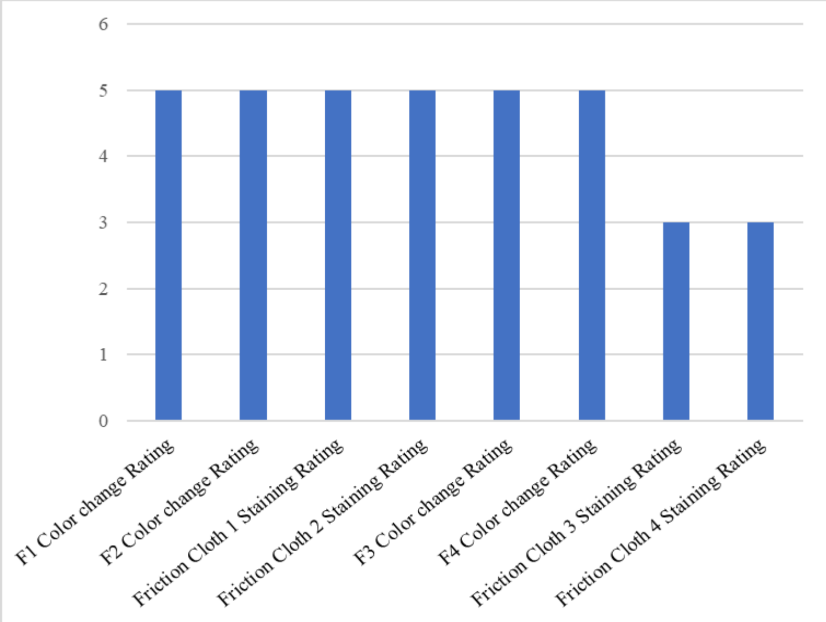


Figure 3. Leather Friction Resistance Color Fastness Grade Chart

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.

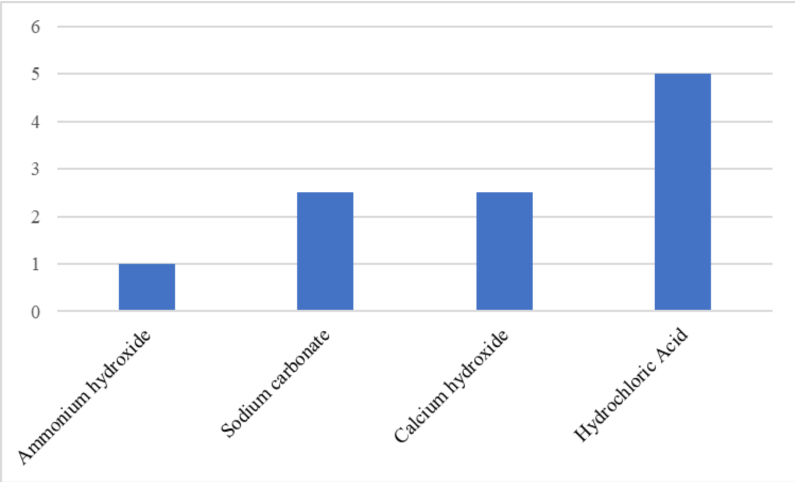


Figure 4. The Impact of Different Solutions on the Color Change Grade of Leather

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

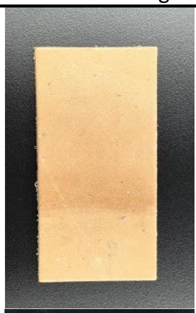
(1) Impact of Acidity and Alkalinity on Color Stability: Acidic solutions (e.g., hydrochloric acid) have the greatest impact on the color stability of leather, resulting in the most noticeable color changes. Alkaline solutions (e.g., ammonium hydroxide, calcium hydroxide) and weakly alkaline solutions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

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CHROMIUM REPLACEMENT WITH ZIRCONIUM MATERIALS IN THE LEATHER TANNING INDUSTRY TO REDUCE POLLUTANTS ON THE PHYSICAL FEATURES OF LEATHER

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CHROMIUM REPLACEMENT WITH ZIRCONIUM MATERIALS IN THE LEATHER TANNING INDUSTRY TO REDUCE POLLUTANTS ON THE PHYSICAL FEATURES OF LEATHER

ABSTRACT. Sheepskin has been used since ancient times for footwear, clothing, and accessories. Tanning transforms raw hide into a durable and stable product, protecting it from microbial degradation, heat, sweat, and moisture. However, traditional tanning processes use dangerous chemicals such as chrome, formaldehyde, and other volatile organic compounds that can pollute the environment and pose health risks. This research aimed to explore the use of zirconium as an alternative, more environmentally friendly tanning material in the sheepskin tanning process. The research method used a Completely Randomized Design (CRD) with four zirconium concentration treatments (7.5%, 10%, 12.5%, and 15%) and three replications. Observed variables include tensile strength, elongation, laxity, thickness, and tear strength of the skin, which are measured using ISO and SNI standards. The data obtained were analyzed using analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT). The research showed that zirconium significantly increases the tensile strength, elongation, thickness, and tear strength of sheepskin. The highest tensile strength was at a concentration of 15% (2440.56 N/mm^2), and the lowest was at 7.5% (1339.05 N/mm^2). Skin elongation and thickness also increased with zirconium concentration, with the highest being at a concentration of 15% (115.59 mm). The highest tear strength was at 15% (393.97 N/mm), while skin laxity showed no significant difference between concentrations. The conclusion of this research is that zirconium can be used as an effective and environmentally friendly alternative tanning material in the sheepskin tanning process.
KEYWORDS: zirconium, sheepskin, mordant, tanning

ÎNLOCUIREA CROMULUI CU ZIRCONIUL ÎN INDUSTRIA DE PIELĂRIE PENTRU A REDUCE ACȚIUNEA POLUANȚILOR ASUPRA CARACTERISTICILOR FIZICE ALE PIEILOR

REZUMAT. Pielea de oaie a fost utilizată încă din antichitate pentru încălțăminte, îmbrăcăminte și accesorii. Procesul de tăbăcire transformă pielea brută într-un produs durabil și stabil, protejând-o împotriva degradării microbiene, căldurii, transpirației și umidității. Însă procesele tradiționale de tăbăcire folosesc substanțe chimice periculoase precum cromul, formaldehida și alte compuși organici volatili care pot polua mediul și care reprezintă riscuri pentru sănătate. Această cercetare și-a propus să exploreze utilizarea zirconiului ca material de tăbăcire alternativ, mai prietenos cu mediul, în procesul de tăbăcire a pielii de oaie. S-a utilizat un Design Complet Randomizat (CRD) ce a cuprins tratamente cu patru concentrații diferite de zirconiu (7,5%, 10%, 12,5% și 15%) și trei repetări. Variabilele observate includ rezistența la tracțiune, alungirea, flexibilitatea, grosimea și rezistența la sfâșiere a pielii, măsurate utilizând standardele ISO și SNI. Datele obținute au fost analizate folosind analiza de varianță (ANOVA) și testul Duncan pentru intervale multiple (DMRT). Cercetarea a arătat că prezența zirconiului conduce la o creștere semnificativă a rezistenței la tracțiune, alungirii, grosimii și rezistenței la sfâșiere a pielii de oaie. Cea mai mare rezistență la tracțiune a fost la o concentrație de 15% (2440,56 N/mm^2), iar cea mai mică la 7,5% (1339,05 N/mm^2). Alungirea și grosimea pielii au crescut, de asemenea, odată cu concentrația de zirconiu, cea mai mare fiind la o concentrație de 15% (115,59 mm). Cea mai mare rezistență la sfâșiere a fost de 15% (393,97 N/mm), în timp ce pentru flexibilitatea pielii nu au existat diferențe semnificative între concentrații. Concluzia acestei cercetări este că zirconiul poate fi utilizat ca un material de tăbăcire eficient și prietenos cu mediul în procesul de tăbăcire a pielii de oaie.
CUVINTE CHEIE: zirconiu, piele de oaie, mordant, tăbăcire

REMPLACEMENT DU CHROME PAR DES MATÉRIAUX À BASE DE ZIRCONIUM DANS L'INDUSTRIE DU TANNAGE DU CUIR POUR RÉDUIRE L'IMPACT DES POLLUANTS SUR LES CARACTÉRISTIQUES PHYSIQUES DU CUIR

RÉSUMÉ : La peau de mouton est utilisée depuis l'Antiquité pour les chaussures, les vêtements et les accessoires. Le tannage transforme la peau brute en un produit durable et stable, la protégeant de la dégradation microbienne, de la chaleur, de la transpiration et de l'humidité. Cependant, les procédés de tannage traditionnels utilisent des produits chimiques dangereux tels que le chrome, le formaldéhyde et d'autres composés organiques volatils qui peuvent polluer l'environnement et poser des risques pour la santé. Cette recherche visait à explorer l'utilisation du zirconium comme matériau de tannage alternatif et plus respectueux de l'environnement pour le tannage de la peau de mouton. La méthode de recherche a utilisé un plan complètement randomisé (CRD) avec quatre traitements de concentration de zirconium (7,5 %, 10 %, 12,5 % et 15 %) et trois répétitions. Les variables observées incluent la résistance à la traction, l'élongation, la flexibilité, l'épaisseur et la résistance à la déchirure de la peau, mesurées selon les normes ISO et SNI. Les données obtenues ont été analysées par analyse de variance (ANOVA) et test de Duncan pour comparaison multiple des moyennes (DMRT). La recherche a montré que la présence du zirconium augmente significativement la résistance à la traction, l'élongation, l''épaisseur et la résistance à la déchirure de la peau de mouton. La plus haute résistance à la traction a été obtenue à une concentration de 15 % (2440,56 N/mm²), et la plus faible à 7,5 % (1339,05 N/mm²). L'élongation et l'épaisseur de la peau ont également augmenté avec la concentration de zirconium, avec un maximum observé à 15 % (115,59 mm). La résistance à la déchirure la plus élevée était de 15 % (393,97 N/mm), tandis que la flexibilité de la peau n'a montré aucune différence significative entre les concentrations. La conclusion de cette recherche est que le zirconium peut être utilisé comme un matériau de tannage efficace et respectueux de l'environnement dans le processus de tannage de la peau de mouton.
MOTS CLÉS : zirconium, peau de mouton, mordant, tannage

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INTRODUCTION

Sheepskin is a natural material that has been used since ancient times for various products, for instance footwear, clothing, and fashion accessories. Tanning is a crucial stage in leather production that transforms raw hides into durable and stable leather products. Deep tanning protects the skin from environmental factors such as microbial degradation, heat, sweat, and humidity [1]. Chromium sulfate has become the primary choice in tanning due to its ability to stabilize collagen fibers and prevent decay [2]. The conventional leather tanning process frequently utilizes harmful chemicals, including chromium, formaldehyde, and other volatile organic compounds. The use of chrome in tanning can lead to the contamination of water and soil with hazardous waste, which contains hexavalent chromium. Hexavalent chromium (Cr^{6+}) is a carcinogenic substance that poses significant risks to both human health and the environment. Apart from that, formaldehyde used in the tanning process is also known to be a compound that is dangerous to human health, especially if exposed in the long term [3].

The use of chromium in leather tanning may present health hazards, particularly concerning allergic contact dermatitis [4]. Organic tanning agents, such as wattle extract and active chlorine, show potential in effectively tanning skin while reducing environmental impact [5]. The development of a cleaner tanning process by replacing chemicals with natural alternatives, such as vegetable tanning, synthetic phenolic products, and aluminum salts, is urgently needed [6]. Incorporating natural plant extracts throughout the leather processing stages, including tanning, re-tanning, dyeing, and degreasing, provides a more sustainable and environmentally friendly approach to leather production [7]. Leather tanned with recycled chromium has similar physical and chemical properties to leather tanned with fresh chromium, indicating a potentially cost-effective and environmentally friendly method [8].

An intriguing alternative in the leather tanning process is the use of zirconium. As a transition metal, zirconium possesses unique chemical properties, such as a high degree of stability and a propensity to form strong shell bonds. These characteristics make zirconium a compelling option as an environmentally friendly and efficient tanning agent. Typically, chromium sulfate and aluminum sulfate are employed in leather tanning to cross-link collagen molecules and stabilize the skin structure. However, zirconium offers similar tanning capabilities while potentially mitigating the environmental harms linked to chromium use [9]. The mixtures of zirconium with other tanning agents, such as multi-branched polymers, have been shown to increase the thickness, softness, and physico-mechanical properties of leather [10]. Zirconium salts mixed with aluminum salts have been identified for their good tanning ability, making them a viable alternative to traditional chrome tanning agents [11].

With increasing awareness of the environmental impact of the tanning industry, the use of zirconium as a tanning agent is becoming a more environmentally friendly alternative to chrome. Zirconium tanning offers advantages in improving the physical and mechanical qualities of leather, such as tensile strength, elasticity, and crack resistance, while reducing the toxic waste generated in the tanning process [12]. Compared to conventional tanning methods, zirconium produces leather with more stable characteristics, is more resistant to environmental degradation, and has a higher level of safety for industrial workers. Therefore, research into tanning using zirconium has the potential to be an innovative solution to create a more sustainable leather industry without compromising the quality of the final product.

Several studies have investigated the application of zirconium salts in leather tanning. [31] developed a green tanning method using POSS-COONa combined with zirconium for cleaner leather production. [21] assessed low pickle processing quality utilizing zirconium tanning systems. Moreover, [10] explored hyperbranched polymer systems incorporating zirconium salts to enhance leather quality. Despite these efforts, most research focuses on blending zirconium with synthetic polymers or other metal salts and utilizes industrial waste as raw material. There remains a paucity of comprehensive studies on the direct use of zirconium salts at varying concentrations, specifically for tanning fresh sheepskin while evaluating multiple critical physical attributes. This study uniquely investigates the direct impact of pure basic zirconium sulfate application at different concentrations on sheepskin quality, aiming to optimize a straightforward and eco-friendly tanning technique without the aid of complex chemical additives.

EXPERIMENTAL

Materials and Instrumentations

The materials used in this study were: sheepskin, plants, flowers, non-iodized salt (NaCl), sodium sulfide (Na_2S), quicklime ($Ca(OH)_2$), ammonium sulfate (ZA), Feliderm, formic acid, sodium formate, sulfuric acid (H_2SO_4). The equipment used in tanning included analytical scales, a fleshing machine, a fleshing knife, gloves, a plastic bucket, pH paper, and a thermometer.

The zirconium tanning agent used was basic zirconium sulfate ($Zr(SO_4)_2$), purchased from Sigma-Aldrich (purity: 99%). No additional chemical modifications were performed prior to application.

The treatments consisted of four levels:

- T1: 7.5% zirconium relative to the wet weight of pickled sheepskin;
- T2: 10% zirconium relative to the wet weight of pickled sheepskin;
- T3: 12.5% zirconium relative to the wet weight of pickled sheepskin;
- T4: 15% zirconium relative to the wet weight of pickled sheepskin.

The concentration percentage refers to the ratio of the zirconium tanning solution added, relative to the pickled pelt's weight.

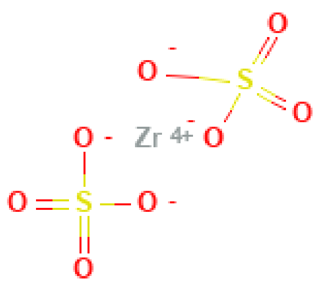

Figure 1. Chemical structure of basic zirconium sulfate: ($Zr(SO_4)_2$)

This complex enables effective cross-linking with collagen fibers during the tanning process, stabilizing the leather structure.

Data Collection and Statistical Analysis

Raw hides, freshly separated from the animal through the skinning process, usually still contain a lot of dirt, hair, and fat. The first stage in the Beam House is soaking where the hides are immersed in water to remove blood, salt, and other impurities. After soaking, the skin will go through a liming process to loosen unwanted hair and tissue. This is done using alkaline solutions such as calcium hydroxide and sodium sulfide. Loose hair is then removed through unhairing, and excess tissue such as the epidermis, is removed through fleshing. After that, the leather undergoes a deliming process to neutralize the chemicals used in shaving and ends with a bating process involving enzymes to soften the leather and remove protein residues, followed by acidification and the final stage of chrome or vegetable tanning. The observation variables in this study are tensile strength, elongation, softness, thickness, and tear strength. The data obtained were tabulated in an Excel program. Analysis of variance (ANOVA) was used to test the effect of various zirconium concentrations in the SPPS program. Mean values between treatments were compared using Duncan's multiple range test (DMRT) when the model detected a significant effect of treatment ($p < 0.05$).

Before entering the discussion of the leather production process as a whole, Table 1 is first presented, which shows the comparison of measurement results between semi-finished products and finished leather products. This table aims to provide an initial understanding of the changes in the physical characteristics and quality of leather during the tanning and finishing process, so that it can be a reference in assessing the effectiveness of each stage in the production process.

Table 1: Differences in measurement results between semi-finished products and finished leather products

Parameters	Semi-finished Products	Finished Leather Products
Thickness (ISO 2589:2002)	Evaluate the tanning process	Ensure consistency of the final product
Softness (ISO 17235:2011)	Checking initial flexibility	Assessing comfort of use
Tensile Strength (ISO 3376:2011)	Assessing raw material quality	Assuring product durability
Elongation (ISO 3376:2011)	Checking basic elasticity	Determining final flexibility
Tear Strength (ISO 3377-1:2011)	Ensures that it does not tear easily before finishing	Tests durability in use

Before describing the process that occurs in the beam house stage in detail, Table 2 summarizes the main stages and the operational parameters used. This table provides a comprehensive overview of the process sequence, the types of chemicals used, and the conditions such as time, temperature, and concentration, required in each stage, thus facilitating an understanding of the entire leather pre-treatment flow.

Table 2: The beam house process

Percentage %	Recipe	Round	Description
1. Soaking Process			
Percentage %	Recipe	Round	Description
200	Water	60 minutes	Rinsed 2x
Washing for 60 minutes to 200% water			
0.3	Wetting Agent	30 minutes	
Rotated 60 Minutes and Rinsed with Flowing Water 40 Minutes			
2. Liming Process (Calcification)			
Percentage %	Recipe	Round	Description
Water conditioned to 100%			
3	Quicklime	20 minutes	
1.5	Na_2S		
Rested 20 minutes			
Run for 40 minutes			
3	Quicklime	20 minutes	
1.5	Na_2S		
Added water up to 300%			
Run for 20 Minutes			
Overnight			
Rotated 150 minutes pH 12-13			
Wash until skin is clean 30 minutes			
3. Reliming Process (Re-fortification)			
Percentage	Recipe	Round	Description
2	ZA	60 Minutes	pH 11
200	Air		
Discharged Water			
4. Deliming Process (Lime Disposal)			
Percentage %	Recipe	Round	Description
200	Air	60 minutes	pH 7-8
2	ZA		
0.3	H_2SO_4		
Reduce water by 50%			
5. Degreasing Process (Fat Elimination)			
Percentage %	Recipe	Round	Description
100	Water	20 minutes	
0.5	Peltech PH-C		
2	ZA		
0.5	H_2SO_4		Diluted with water 1:20 side entry
6. Bating Process (Protein Erosion)			
Percentage %	Recipe	Round	Description
2	Feliderm	60 minutes	Each treatment is rotated together and checked by permeability test/thumb test.
Wastewater			

7. Pickle Process (Acidification)			
Percentage %	Recipe	Round	Description
10 100	Salt Water	10 minutes	
1.5	FA	5x15 minutes	Dissolved with water 1:10
0.5	H_2SO_4	2x20 minutes	Dissolved with water 1:20
BCG test pH 2.5 Rotated 60 minutes			

8. The Tanning Process			
Percentage %	Recipe	Round	Description
7.5	Chrome Sulfate	60 minutes	Penetration check
7.5	Zirconium	60 minutes	Penetration check
10	Zirconium	60 minutes	Penetration check
12.5	Zirconium	60 minutes	Penetration check
15	Zirconium	60 minutes	Penetration check
Overnight Run for 60 minutes			
2	Natrium Phosphate	2x20 minutes	
In BCG check pH <4			
0.5	Baking soda	2x20 minutes	Dissolved with water 1:10
BCG check (yellow color)			
0.5	Baking soda	2x20 minutes	Dissolved with water 1:10
100°C wrinkle temperature test			
0.5	Baking soda	2x20 minutes	
Overnight Run for 120 minutes Wrinkle temperature tested with glycerin solution			

RESULTS AND DISCUSSIONS

The laboratory analysis results indicated that varying levels of zirconium had a highly significant impact on tensile strength, elongation, thickness, and tear strength ($P>0.01$), while the effect on laxity was not significant ($P>0.05$). The average skin quality data from the study are summarized in Table 3. The results of tanning with zirconium during the study period were highest at 15% concentration and lowest at 7.5%. The results of tensile strength, elongation, softness, thickness, and tear strength ranged from 2440.56 N/mm^2, 115.59%, 7.36%, 1.24 mm, and 393.97 N, respectively.

Table 3: Results of quality testing of tanned leather with zirconium

Percentage	Materials	Tensile strength (MPa)	Elongation (%)	Softness (%)	Thickness (mm)	Tear Strength (N)
7.5%	Chrome	1205.00±85.53a	49.43±3.37a	5.45±0.81	0.86±0.27a	181.91±11.83a
7.5%	Zirconium	1339.05±94.94a	59.17±5.56a	6.66 ± 0.94	0.96 ± 0.11a	189.91±14.99a
10%	Zirconium	2125.25±72.63b	72.89±2.14b	7.18 ± 0.60	0.98±0.70a	260.62±19.79b
12.5%	Zirconium	2242.31±87.18c	89.06±2.48c	7.26 ± 0.95	1.10±0.15b	284.16±18.64c
15%	Zirconium	2440.56±90.19d	115.59±9.50d	7.36 ± 0.30	1.24 ± 0.08b	393.97±17.54d

Note: Different superscripts indicate that the treatments have significantly different effects ($P>0.01$).

Tensile Strength

The highest tensile strength was recorded at a 15% zirconium concentration (2440.56±90.19d), while the lowest was observed at a 7.5% concentration (1339.05±94.94a). Generally, tensile strength increases with higher tanning agent concentrations due to enhanced dispersion of collagen fibers within the skin, which is driven by the tanning agent [13]. Tensile strength measures the ability of leather to withstand tension without being damaged. In the study, results showed that the pre-mordant method produced the highest tensile strength compared to other methods. The use of chromium at 4% also increased the tensile strength of the leather [14-16]. The increased interaction between the tanning agent and collagen fibers contributes to higher tensile strength by regulating the charge properties of the tanned skin [17]. According to [18] higher tannin concentration leads to better tensile strength properties. Tannin concentration can increase tensile strength and provide additional benefits such as resistance to microbes and improved color retention in tanned leather [19]. One of the main penetration mechanisms is the electrostatic interaction between tanning agents and collagen fibers. [20] showed that negatively charged tanning agents diffuse into collagen fibers due to electrostatic attraction with positively charged amino groups present in collagen.

Similarly, the study highlights that chrome-free tanning agents, which often include synthetic tannins, result in superior tensile and grain strength due to their effective filling of the leather matrix. One of the main reasons for the increase in tensile strength is the effective interaction between the tanning agent and the collagen fibers. This improvement is due to the ability of the tanning agent to fill the leather matrix more effectively, resulting in better fiber bonding [21]. The duration of exposure to tanning agents also affects penetration depth. [22] noted that the interaction between chrome tanning agents and collagen fibers is influenced by the soaking time, which can enhance the penetration of these agents into the collagen matrix. [23] found that adjusting the pH during the tanning process promotes the deprotonation of carboxyl groups on collagen, enhancing their interaction with chromium ions and facilitating deeper penetration into the collagen matrix.

Elongation

Based on the mean values in Table 1, which are 59.17±5.56a (7.5%), 72.89±2.14b (10%), 89.06±2.48c (12.5%), and 115.59±9.50d (15%), the elongation of sheepskin increased with the addition of zirconium concentration. Skin elasticity is the ability of the skin to stretch or elongate without damage to its structure. Leather can withstand elastic deformation and return to its original shape after the stretching force is released. Leather elongation is important in various applications, including in the tanning industry [24]. Zirconium, as a tanning agent, interacts with the collagen structure, promoting cross-linking between collagen molecules. These cross-links are essential for improving the elasticity and flexibility of leather. Studies have shown that zirconium can produce improvements in the mechanical properties of leather, including elongation at break [21]. The addition of certain concentrations of tanning agents can improve the physical characteristics of sheepskin, including elongation. The tanning process alters collagen fibers, increasing their stability and elasticity [9].

Elongation of tanned leather can vary based on the source and age of the leather. Skins cut from elderly subjects tend to exhibit decreased elongation ability, which may affect the overall elongation properties of tanned leather [25]. The use of mimosa tannins can increase tensile strength and elongation, which indicates its effectiveness as a tanning agent not only preserves leather but also improves its physical properties [19]. The greater amount of collagen fibers in sheepskin leads to increased tensile strength and elasticity, which are essential to achieve the desired elongation at fracture [26]. Fatliquoring is the process of incorporating oil into the leather. Fatliquoring methods to increase the softness and elasticity of tanned leather, thereby improving its elongation properties [27]. Elongation or stretchability of leather refers to how far the leather can stretch before breaking. The best elongation results are generally found in leathers tanned with methods that take into account natural ingredients, such as enzymes or plant extracts. Elongation values ranged from 40-60% in some of these studies, indicating sufficient stretchability for the needs of the textile industry and leather-based products [16, 28, 29].

Softness

Table 1 shows that the best skin laxity can be seen from the highest average, which was 7.36±0.30 found in the 15% zirconium concentration treatment. The density and compactness of the skin can affect its ability to retain moisture and lubrication. When the skin is tight and dense, there is less space for oil to lubricate the skin fibers, which can lead to decreased skin laxity [30]. Tanning agents can get between the skin's collagen fibers, creating gaps between them that increase their range of motion. This allows the skin's collagen fibers to become more elastic and increases its relative laxity [31]. Zirconium sulfate has optimal filling properties that facilitate the dispersion of collagen fibers. This significantly increases skin density and laxity, providing better results [32].

The mechanical properties of leather, including its elasticity and tensile strength, play an important role in determining softness. The arrangement of collagen fibers within the skin can affect its softness. A looser fiber structure usually results in softer leather. The drying process during leather production can increase softness, as the drying process causes fine spaces between the fibrils, making the leather softer and more flexible [33]. The structural integrity of collagen fibers within the skin also affects its softness. The arrangement and density of these fibers can affect how well moisturizing agents can penetrate and lubricate the skin. A well-distributed collagen network allows for better oil absorption, leading to increased softness [19]. The incorporation of zirconium in the tanning process results in an improvement in the softness of the leather, which is due to the effective interaction between zirconium ions and the collagen matrix [34]. The concentration of zirconium plays a crucial role in determining the final softness of the leather. As noted by [10] the use of zirconium in tanning processes can lead to enhanced softness, which is essential for producing high-quality leather. The level of leather softness is influenced by the technique used in the tanning process. In the tanning study, pre-mordant resulted in the highest softness value. The use of gelatin in finishing was also shown to retain the softness of the leather after the coating process, which is suitable for products such as jackets and bags [35, 36].

Thickness

As shown in Table 1, the mean thickness values were 0.96±0.11a (7.5%), 0.98±0.70a (10%), 1.10±0.15b (12.5%), and 1.24±0.08b (15%), indicating that sheepskin thickness increases with higher zirconium concentrations. Thickness is a critical factor that greatly influences leather quality and characteristics, affected by variables such as leather type, tanning process, and composition. Different animal skin regions—hips, upper shoulders, back, ribs, and girdle—exhibit variations in thickness, with some areas being thicker [37]. The tanning process plays a crucial role in determining hide thickness, as the amount of tanning agent affects collagen binding and fills empty spaces within the skin fibers, thus impacting overall thickness [38]. The higher the thickness increases, the higher the tanning agent solution diffuses into the collagen matrix [39].

The histological characteristics of the skin, including its thickness, can vary not only between species but also within the same species based on factors such as age, nutrition, and environmental exposure [26]. In addition to biological characteristics, the choice of tanning agents also plays a crucial role in determining the thickness of the final leather product. The amount of tanning agent bound to the collagen and the filling of empty spaces within the skin fibers can significantly affect the overall thickness of the tanned leather [18]. environmental conditions, such as seasonal changes, can also impact skin thickness. [40] noted that seasonal variations could lead to differences in the mechanical properties of tanned furs, which are closely related to the thickness of the skin. This suggests that the time of year and the conditions under which the animals are raised can have lasting effects on the quality of the leather produced. The thickness of the leather is regulated through the tanning method and the materials used. In research with tanning, thickness is optimized through processing with plants or other natural substances. The thickness of the leather is usually maintained to maintain strength while remaining flexible to the needs of the final product [15, 16, 29].

Tear Strength

The average values presented in Table 1 reveal that the highest tear strength occurred at the 15% concentration (393.97±17.54c), whereas the lowest was at 7.5% concentration (189.91±14.99a). This is consistent with the study by [41] that tear strength values for different breeds of sheep were reported to be around 401.5 N/mm for one group, 361.2 N/mm for another, and 421.0 N/mm for a third, highlighting the influence of genetic factors on skin quality. Increasing the concentration of the tanning agent enhances the tear strength of the skin due to the formation of bonds between the agent and the skin's protein structure, resulting in improved strength and resilience [42]. Several factors, including fiber toughness, flexibility, compactness, and the uniformity of collagen fibers, influence tear strength [43]. Additionally, the tear strength quality may be attributed to differences in the polyphenol profile, which can affect fiber interactions and material durability [44]. Increased collagen fiber alignment was associated with increased tear strength and peel strength, indicating that structural collagen is a key factor in the mechanical performance of leather [45]. In addition to the type of tanning agent, specific characteristics of the animal hide also contribute to tear strength. [26] reported that the arrangement of leather fibers, which is denser in the dorsal spine area, can result in higher tensile and tear strength. Structural differences between the fiber and corium layers of the skin also affect tear strength. The structure of the corneal fiber is better able to inhibit the spread of the tear through mechanisms such as blunting of the tear tip and fiber drag. Tear strength measures the resistance of leather to forces that can cause tearing. Methods such as the use of iron salts or pre-mordanting in tanning show improvement in tear strength. Tear strength ranged from 10-15 N/mm in some test samples, indicating good durability for applications that require high durability [35, 36, 46].

CONCLUSION

Zirconium presents itself as a highly promising, environmentally benign alternative to traditional chromium-based tanning agents. By forming strong bonds with collagen fibers, zirconium not only enhances the physical and mechanical properties of the leather but also minimizes hazardous waste production. This research provides a simpler, more sustainable leather tanning solution that maintains high leather quality without reliance on auxiliary chemical modifications.

Conflict of Interest

The Authors have declared no conflict of interest.

Novelty Statement

The novelty of this study lies in its direct application of pure zirconium salts at varying concentrations on sheepskin without combining additional complex additives. The approach simplifies the tanning process while significantly improving tensile strength, elongation, and tear resistance, offering a practical, sustainable alternative to chromium tanning.

Author Contribution

AP, YE, MZA, and RAA designed and coordinated the study. AP, YE, and MZA supervised the experiment. RAA experimented, analyzed the data, and drafted the manuscript. AP, YE, and MZA took part in critically checking this manuscript. All authors read and approved the final manuscript.

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DESIGN AND DEVELOPMENT OF HANDICRAFTS BASED ON WASTE VEGETABLE-TANNED LEATHER MATERIALS

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DESIGN AND DEVELOPMENT OF HANDICRAFTS BASED ON WASTE VEGETABLE-TANNED LEATHER MATERIALS

ABSTRACT. This research investigates the reuse of waste vegetable-tanned leather materials in the leather industry. Through systematic analysis of the physical properties of waste vegetable-tanned leather materials, this study explores their potential applications in handicraft design and production. The research conducts tensile strength, tear resistance, and abrasion resistance performance tests on vegetable-tanned leather materials according to relevant standards (ISO 3376, ISO 3377-2, ISO 178076-1), and develops design solutions based on the test results. Tests show that waste vegetable-tanned leather materials have longitudinal and transverse tensile strengths of 16.487 MPa and 13.008 MPa respectively, an average tear strength of 112.164 N, and an average abrasion mass loss of only 23 mg. The research findings indicate that these materials possess excellent physical properties, and waste vegetable-tanned leather materials have significant reuse value. Through appropriate process design, they can be transformed into commercially valuable handicrafts, including apparel accessories, stationery items, and artistic decorative pieces. This research provides new insights into the circular utilization of waste vegetable-tanned leather materials and has important implications for promoting the translation from theory to practice of sustainable development in the leather industry.

KEYWORDS: vegetable-tanned leather, waste material reuse, handicraft design, sustainable development

PROIECTAREA ȘI REALIZAREA UNOR PRODUSE ARTIZANALE DIN DEȘEURI DE PIELE TĂBĂCITĂ VEGETAL

REZUMAT. Acest studiu de cercetare investighează reutilizarea deșeurilor de piele tăbăcită vegetal în industria de pielărie. Prin analiza sistematică a proprietăților fizice ale deșeurilor de piele tăbăcită vegetal, acest studiu explorează potențialele lor aplicații în designul și realizarea unor obiecte artizanale. S-au efectuat teste de rezistență la rupere, rezistență la sfâșiere și rezistență la abraziune a deșeurilor de piele tăbăcită vegetal conform standardelor relevante (ISO 3376, ISO 3377-2, ISO 178076-1) și s-au dezvoltat soluții de design pe baza rezultatelor obținute. Testele arată că deșeurile de piele tăbăcită vegetal au rezistențe la rupere longitudinală și transversală de 16,487 MPa, respectiv 13,008 MPa, o rezistență medie la sfâșiere de 112,164 N și o pierdere medie de masă prin abraziune de doar 23 mg. Constatările cercetării indică faptul că aceste materiale prezintă proprietăți fizice excelente, iar deșeurile de piele tăbăcită vegetal au o valoare semnificativă de reutilizare. Prin proiectarea adecvată a procesului, acestea pot fi transformate în articole artizanale cu valoare comercială, inclusiv accesorii vestimentare, articole de papetărie și piese artistice decorative. Această cercetare oferă noi perspective asupra utilizării circulare a deșeurilor de piele tăbăcită vegetal și are implicații importante pentru promovarea tranziției de la teorie la practică a dezvoltării durabile în industria de pielărie.

CUVINTE CHEIE: piele tăbăcită vegetal; reutilizarea deșeurilor; design de obiecte artizanale; dezvoltare durabilă

CONCEPTION ET DÉVELOPPEMENT D’ARTICLES ARTISANAUX À PARTIR DE DÉCHETS EN CUIR TANNÉ VÉGÉTAL

RÉSUMÉ. Cette recherche étudie la réutilisation des déchets en cuir tanné végétal dans l’industrie du cuir. À travers une analyse systématique des propriétés physiques des déchets en cuir tanné végétal, cette étude explore leurs applications potentielles dans la conception et la production artisanale. La recherche effectue des tests de résistance à la traction, de résistance à la déchirure et de résistance à l’abrasion des déchets en cuir tanné végétal selon les normes pertinentes (ISO 3376, ISO 3377-2, ISO 178076-1) et développe des solutions de conception basées sur les résultats des tests. Les tests montrent que les déchets en cuir tanné végétal présentent des résistances à la traction longitudinale et transversale de 16,487 MPa et 13,008 MPa respectivement, une résistance moyenne à la déchirure de 112,164 N et une perte de masse moyenne par abrasion de seulement 23 mg. Les résultats de la recherche indiquent que ces matériaux possèdent d’excellentes propriétés physiques, et que les déchets en cuir tanné végétal ont une valeur de réutilisation significative. Grâce à une conception appropriée du processus, ils peuvent être transformés en produits artisanaux commercialement viables, notamment des accessoires vestimentaires, des articles de papeterie et des pièces décoratives artistiques. Cette recherche apporte de nouvelles perspectives sur l’utilisation circulaire des déchets en cuir tanné végétal et a des implications importantes pour promouvoir la transition de la théorie à la pratique du développement durable dans l’industrie du cuir.

MOTS CLÉS : cuir tanné végétal ; réutilisation des déchets ; conception artisanale ; développement durable

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INTRODUCTION

With the increasing emphasis on sustainable development and environmental awareness, circular economy and green manufacturing have become crucial development directions for contemporary manufacturing industries [1]. In the leather processing industry, a large quantity of edge trimmings and scrap materials are directly disposed of as waste, not only resulting in resource waste but also potentially burdening the environment [2]. If these trimmings could be redesigned and utilized in production, it would further promote the development of the leather industry [3]. Vegetable-tanned leather, as a unique leather material, possesses characteristics of natural environmental protection and superior quality, making the reuse of its waste materials significant in both environmental and economic terms [4]. How to effectively utilize these waste vegetable-tanned leather materials to achieve resource recycling has become a topic of common concern in both academic and industrial circles.

In recent years, domestic and international scholars have conducted extensive research on the application of vegetable-tanned leather materials. Chen Wanri's research indicates that vegetable-tanned leather has gained increasing consumer favor due to its natural and environmentally friendly characteristics, as it contains no toxic heavy metals and is biodegradable, meeting people's pursuit of an eco-friendly lifestyle [5]. In terms of process innovation, Xie Jiali *et al*. explored the application of plant-based indigo dyeing on vegetable-tanned leather, injecting new vitality into traditional handicrafts by combining vegetable-tanned leather craftsmanship with indigo dyeing, providing innovative ideas for vegetable-tanned leather artistic creation [6]. Zhou Yi combined wax dyeing techniques with vegetable-tanned leather, opening up new avenues for decorating vegetable-tanned leather [7]. Zhang Yingyue and Wei Yixiu respectively studied the application of wet rubbing art and water transfer art on vegetable-tanned leather products, enriching the artistic expression forms of vegetable-tanned leather [8, 9]. These studies provide important technical support and innovative ideas for the reuse of vegetable-tanned leather waste.

Based on the above research background, this study aims to explore the potential applications of waste vegetable-tanned leather materials in handicraft design and production through systematic experimental research and innovative design. The research begins with material performance testing, conducting comprehensive evaluations of basic properties such as tensile strength, tear resistance, and abrasion resistance of waste vegetable-tanned leather materials, providing scientific basis for their reuse. Building on this foundation, through process innovation and design practice, the study develops processing techniques and product design solutions suitable for the characteristics of waste vegetable-tanned leather materials, achieving the unity of environmental value and economic benefits.

EXPERIMENTAL

Materials and Methods

This research conducted tensile strength testing, double-edge tear testing, and Taber abrasion testing according to relevant standards (ISO 3376, ISO 3377-2, ISO 178076-1). Tests were performed under standard laboratory conditions (temperature 23±2°C, relative humidity 50±5%), with samples conditioned in this environment for more than 8 hours prior to testing.

Experimental Materials

1. Leather Samples

Vegetable-tanned leather waste materials were cut into shapes required for experimental equipment.

Sixteen standardized vegetable-tanned leather samples were divided into the following groups according to experimental requirements:

(1) Leather tensile strength test: 6 samples.

(2) Leather double-edge tear test: 6 samples.

(3) Leather Taber abrasion test: 4 samples.

2. Experimental Equipment

(1) Basic measuring equipment: constant-pressure thickness gauge, vernier caliper, tensile testing machine.

(2) Specialized testing equipment: leather tensile testing machine, leather double-edge tear strength testing machine, Taber abrasion tester.

Experimental Methods

(1) Leather Tensile Strength Test

Test parameters: Temperature 23±2°C, tensile speed 100mm/min, gauge length 50mm. Testing used a constant-pressure thickness gauge to measure sample thickness (accurate to 0.01mm), measured sample width (accurate to 0.1mm), and employed a tensile testing machine for the tensile test, recording the breaking force value.

(2) Leather Double-Edge Tear Test

Sample pretreatment: Samples were conditioned in laboratory environment for over 8 hours to achieve temperature and humidity equilibrium. Samples were cut from leather specimens according to the standard, and tested using a tensile testing machine at a constant speed of 100 millimeters/minute, recording the maximum force during the tearing process.

(3) Taber Abrasion Test

Test conditions: CS-10 abrasive wheel, load 500g, rotation speed 60±5r/min, number of rotations 500r. The grinding wheel underwent pre-abrasion treatment before testing, and once formal testing began, the sample's wear condition was observed and recorded, with mass loss recorded after test completion.

RESULTS AND DISCUSSION

Experimental Data Presentation

Table 1: Leather Tensile Strength Test Data

Sample Name	Vegetable-tanned leather					
Direction	Parallel to backbone line			Perpendicular to backbone line		
Sample No.	1	2	3	4	5	6
Width/mm	9.88	9.79	9.84	9.86	9.86	9.85
Thickness/mm	1.43	1.44	1.40	1.56	1.54	1.51
Tensile Rate (mm/min)	100					
Gauge Length/mm	50					
Tensile Strength/Mpa	15.573	17.888	15.999	11.029	12.517	15.478
Mean Value/Mpa	16.487			13.008		
Overall Mean/Mpa	14.747					
Breaking Elongation/%	38.333	39.583	39.758	41.331	40.165	50.157
Mean Value/%	39.225			43.884		
Overall Mean/%	41.555					

The tensile strength test results for vegetable-tanned leather samples in different directions are shown in Table 1. Samples parallel to the backbone line demonstrated an average tensile strength of 16.487 MPa with a standard deviation of 1.231 MPa, while samples perpendicular to the backbone line showed an average of 13.008 MPa with a standard deviation of 2.287 MPa. The significant difference between these two directions ($P<0.05$) indicates clear mechanical anisotropy in the vegetable-tanned leather material, primarily originating from the natural fiber arrangement structure of the leather.

The experimental data also revealed notable differences in breaking elongation between the two directions. Samples parallel to the backbone line showed an average breaking elongation of 39.225% with relatively low dispersion, while samples perpendicular to the backbone line demonstrated an average of 43.884% with a wider distribution range (41.331%-50.157%). This result indicates that samples perpendicular to the backbone line possess superior extensibility properties.

Table 2: Leather Double-Edge Tear Test Data

Sample Name	Vegetable-tanned leather					
Test Speed (mm/min)	100					
Direction	Parallel to backbone line			Perpendicular to backbone line		
Sample No.	1	2	3	4	5	6
Thickness/mm	1.44	1.45	1.42	1.38	1.48	1.41
Maximum Force/N	111.306	102.529	93.654	115.131	132.194	118.17
Mean Value/N	102.496			121.832		
Overall Mean/N	112.164					

Test results showed distinct directional differences in tear strength: samples perpendicular to the backbone line averaged 121.832 N, significantly higher than the parallel direction's 102.496 N. The overall tear strength distribution ranged from 93.654 to 132.194 N, with a total average of 112.164 N. This significant directional difference (approximately 18.9%) primarily results from the natural fiber arrangement structure and the impact of the tanning process on fiber structure. Sample thickness distribution ranged from 1.42 to 1.48 mm, showing good thickness uniformity with low data dispersion, indicating that the waste vegetable-tanned leather material maintained excellent mechanical properties fully meeting handicraft production requirements.

Table 3: Leather Taber Abrasion Test Data

Sample Name	Vegetable-tanned leather	
Weight Load/g	500	
Wheel Type	CS-10	
Speed/rpm	(60±5)	
Rotations/r	500	
	Mass Loss Results/mg	Average/mg
Sample 1	7	/
Sample 2	19	
Sample 3	21	23
Sample 4	28	

Results showed that except for Sample 1's mass loss (7 mg) which differed significantly from other samples, Samples 2, 3, and 4 showed mass losses of 19 mg, 21 mg, and 28 mg respectively, with an average mass loss of 23 mg. No visible damage was observed on the surface of any samples, indicating good abrasion resistance of the waste vegetable-tanned leather material. The relatively stable mass loss data from Samples 2, 3, and 4 reflects the reliability of the material's abrasion resistance properties, providing important technical support for the application of waste vegetable-tanned leather materials in handicraft design and production.

Discussion

Based on the aforementioned experimental results, waste vegetable-tanned leather materials demonstrated excellent mechanical properties and wear resistance characteristics, providing reliable technical support for their redesign and development. The tensile strength testing revealed that the material achieved an average tensile strength of 16.487 MPa in the direction parallel to the backbone line and 13.008 MPa perpendicular to it, with a significant directional difference. Tear strength testing showed that samples perpendicular to the backbone line averaged 121.832 N, higher than the parallel direction's 102.496 N; and in the wear resistance testing, the material demonstrated stable wear resistance performance with an average mass loss of only 23 mg and no visible surface damage. These data comprehensively verify that waste vegetable-tanned leather materials maintain excellent physical properties, with superior wear resistance, making them particularly suitable for handicrafts intended for long-term use.

These experimental results not only confirm the practical value of waste vegetable-tanned leather materials but also provide scientific basis for exploring their diversified applications in the design field. Literature research further supports the extensive application potential of vegetable-tanned leather materials. Zhang [10] demonstrated the unique effects of vegetable-tanned leather in tie-dye art in his research. Zhao [11-12] explored the characteristics of vegetable-tanned leather as a quality leather carving material and, from the perspective of experience economy, proposed new ideas for handmade leather goods development, emphasizing the importance of consumer participation in promoting innovation. Luo *et al*. [13] elaborated on various interesting expression forms of handmade leather goods, including relief carving, patchwork, painting, and embroidery techniques. Through these literature analyses, it can be found that vegetable-tanned leather possesses rich artistic expression forms and craft potential. Combined with the experimental data of this research, it provides a comprehensive theoretical and practical foundation for innovative applications of waste vegetable-tanned leather materials.

These excellent properties of vegetable-tanned leather give it unique advantages in the field of sustainable design. Based on experimental data and literature research, several key aspects should be considered in the redesign and development of waste vegetable-tanned leather materials: first, material orientation should be rationally selected according to the stress points of different product parts, fully utilizing the material's directional characteristics; second, based on the material's wear resistance properties, practical handicrafts suitable for daily use can be developed; and finally, material extensibility differences should be fully considered in process design to optimize manufacturing techniques. This design approach based on experimental data not only improves the utilization efficiency of waste materials but also ensures product quality and service life, achieving unity of environmental and practical value.

DESIGN AND DEVELOPMENT OF WASTE VEGETABLE-TANNED LEATHER MATERIALS

Design Concept

In terms of product positioning, this design solution primarily utilizes vegetable-tanned leather fragments as the core raw material. Through the integration of diverse elements and contemporary design concepts, it aims to create a series of distinctive handicrafts that not only embody environmental sustainability but also achieve aesthetic appeal and functional utility, meeting the diversified demands of modern consumers.

The product design encompasses three major categories: apparel accessories, stationery items, and artistic pieces. In the realm of apparel accessories, the focus is predominantly on practical everyday items such as vegetable-tanned leather wallets, handbags, belts, and footwear. These products fully exploit the flexibility and malleability of vegetable-tanned leather, being customized according to specific client requirements to achieve an optimal synthesis of aesthetic merit and functional value. The stationery series includes notebook covers, bookmarks, and pen holders, which are crafted through precise cutting, stitching, and embossing techniques, incorporating specialized dyeing processes such as wax-resist and paste-resist dyeing to accentuate the distinctive tactile qualities inherent to vegetable-tanned leather. In terms of artistic creation, the material is employed in leather carving artworks and installation pieces, utilizing diverse crafting techniques including relief carving, modular composition, and chromatic treatment to fully manifest the unique artistic characteristics of the vegetable-tanned leather medium.

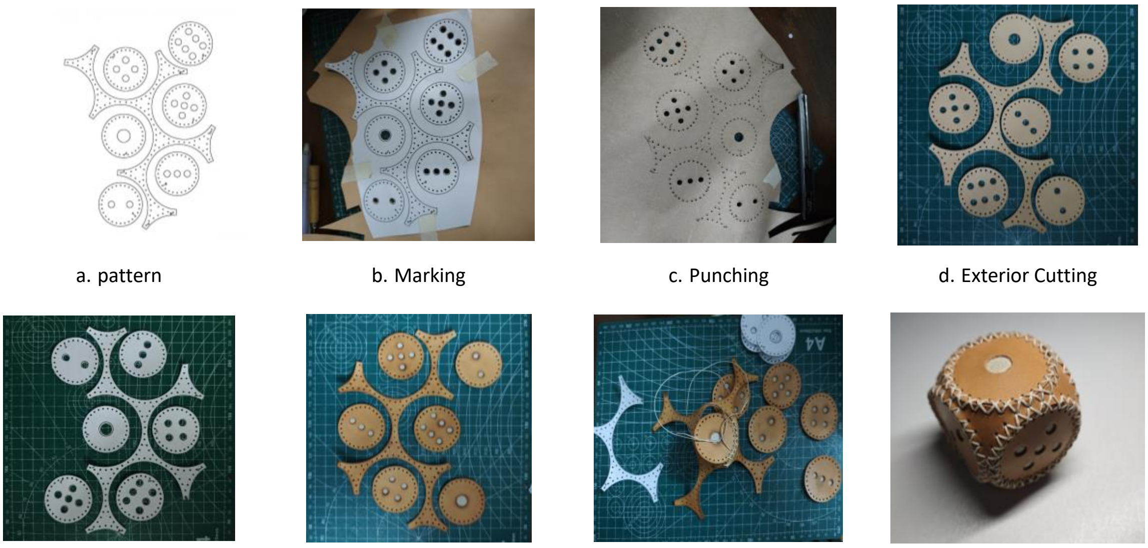
The technical route comprises three principal phases. The initial phase involves raw material acquisition and processing, where waste vegetable-tanned leather is collected from leather processing facilities and subsequently undergoes systematic classification, cleaning, and pretreatment to achieve the requisite raw material standards for production utilization. The second phase encompasses manufacturing processes, including cutting and sewing operations as well as crafting techniques. The cutting and sewing process incorporates digital scanning technology for computer-aided pattern development, followed by precision cutting in accordance with digitally generated design specifications, culminating in manual stitching procedures. The crafting techniques involve pattern engraving executed using specialized carving implements, surface embellishment accomplished through printing and embossing techniques, and the application of dyeing methods such as wax-resist and paste-resist processes to achieve varied color gradations. Additionally, surface lustre can be modified through the application of finishing agents to optimize the material's visual characteristics. The final phase involves product assembly and quality control, where individual components are assembled at designated workstations, concurrent with quality control inspections to ensure compliance with design specifications and quality standards.

DESIGN EXAMPLES

Based on the material performance test results and design concepts of this research, the research team developed a vegetable-tanned leather dice-shaped pendant as a practical application case for the reuse of waste vegetable-tanned leather materials. This product fully embodies the manufacturing process that combines digital design with traditional craftsmanship, while demonstrating an efficient utilization solution for small, fragmented vegetable-tanned leather materials.

In the design phase, computer-aided design software was used to create precise drawing templates, ensuring standardization of product dimensions and reproducibility of production. This digital design approach not only improved material utilization but also guaranteed product consistency, laying the foundation for batch production. The template design specifically considered the directional strength characteristics of vegetable-tanned leather, optimizing the cutting direction based on test data to ensure the durability of the finished product.

The manufacturing process followed a systematic workflow: first, fragments of appropriate size were carefully selected from waste vegetable-tanned leather materials according to the geometric requirements of the dice shape; second, the printed precise template was placed on the vegetable-tanned leather surface for marking; then, precise cutting was performed according to the markings; subsequently, professional tools were used to punch holes at predetermined positions in preparation for subsequent stitching; finally, manual stitching techniques were employed to assemble the various components into a three-dimensional dice shape, ensuring that the stitching was both secure and aesthetically pleasing.



a. pattern b. Marking c. Punching d. Exterior Cutting

e. Interior Cutting f. Interior-Exterior Bonding g. Stitching h. Finished Product Display

Figure 1. Dice Pendant Manufacturing Process Diagram

Figure 2. Dice Pendant Display Image

The finished dice pendant exhibits aesthetic qualities that are both simple and refined, preserving the natural texture of vegetable-tanned leather while demonstrating the material's plasticity through an intricate three-dimensional structure. As a bag accessory, this product not only serves a decorative function but also embodies eco-friendly concepts, fully demonstrating the application potential of waste vegetable-tanned leather materials in small accessory design. Market feedback indicates that such environmentally creative products are well-received by consumers, with young consumer groups in particular highly appreciating their unique design and sustainable concept.

This case validates the practicality of the waste vegetable-tanned leather material reuse design method proposed in this research, while also proving the commercial value of small, fragmented vegetable-tanned leather in the premium accessory sector, providing valuable reference for innovative applications of waste materials.

CONCLUSIONS

Through systematic experimental analysis and design practice, this study explored the application value of waste vegetable-tanned leather materials in handicraft design and production. The experimental results clearly demonstrate that waste vegetable-tanned leather materials maintain excellent physical properties after standardized treatment, specifically exhibiting longitudinal and transverse tensile strengths of 16.487 MPa and 13.008 MPa respectively, an average tear strength of 112.164 N, and an average abrasion mass loss of only 23 mg with no visible surface damage. These test data reveal significant directional differences in mechanical properties, providing key technical references for subsequent product design.

Based on these experimental results, this study developed a complete system for the reuse of waste vegetable-tanned leather materials, establishing a standardized technical route from material recovery and classification to product manufacturing. Through process innovation, we successfully transformed waste materials into commercially valuable handicrafts, such as dice-shaped pendants, achieving efficient resource utilization. Market feedback indicates that products integrating environmental concepts with aesthetic design are particularly welcomed by young consumer groups, validating the practicality and commercial viability of our design methods.

The main contributions of this research are: (1) providing quantitative data on the performance of waste vegetable-tanned leather materials through scientific testing; (2) developing design solutions suitable for different product categories (apparel accessories, stationery items, and artistic decorations); (3) establishing a manufacturing process that combines digital design with traditional craftsmanship. These achievements not only provide practical solutions for the circular utilization of waste vegetable-tanned leather materials but also offer valuable reference models for sustainable development in the leather industry.

Future research directions include: further optimization of material property treatment technologies, development of more diverse product design solutions, and exploration of deeper integration models between environmental benefits and economic value. The methods and cases demonstrated in this study are expected to provide inspiration for waste material reuse in the leather industry and other material fields, promoting the practical application of circular economy concepts in manufacturing.

Acknowledgements

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EUROPEAN RESEARCH AREA

COTANCE NEWSLETTERS

Starting with January 2019, the COTANCE Council has issued a monthly ***COTANCE Newsletter*** with the purpose of **promoting an improved image of leather** to relevant decision makers and domestic stakeholders including Members of the European and National Parliament, Governmental authorities, Ministerial officers, Customers of the leather industry, Brands, Retail chains, Relevant NGOs, Designers, etc. The monthly newsletters present topics that tell the truth about a controversial aspect or a fact that is not well known by the general public to bring about a better understanding of leather and the European leather industry, as well as a positive predisposition to legislate in favor of the leather industry. The newsletters are available in seven languages at https://www.euroleather.com/leather/newsletter, and were also published in the 2019-2024 issues of *Leather and Footwear Journal*. Newsletter 3 of 2025 is given below.

NEWS 3/2025

Zero Allocation Explained

Zero Allocation, PEF, PEFCR – who is able to understand all this? Do I really need it? We are convinced you will be happy to know a little about these "environmental impacts" – if we are able to explain it clearly.

The EU launched in 2013 the Product Environmental Footprint (PEF) initiative; developing in public-private partnership an LCA methodology for measuring the environmental footprint of products placed on the EU market. Different industries volunteered to develop Product Environmental Footprint Category Rules (PEFCRs). Leather developed one and today there are some 19, including for apparel & footwear. The idea behind the PEF method is great, as it aims to reduce uncertainties present in other methodologies across different disciplines and to unify the way environmental impacts are measured and compared across the EU.

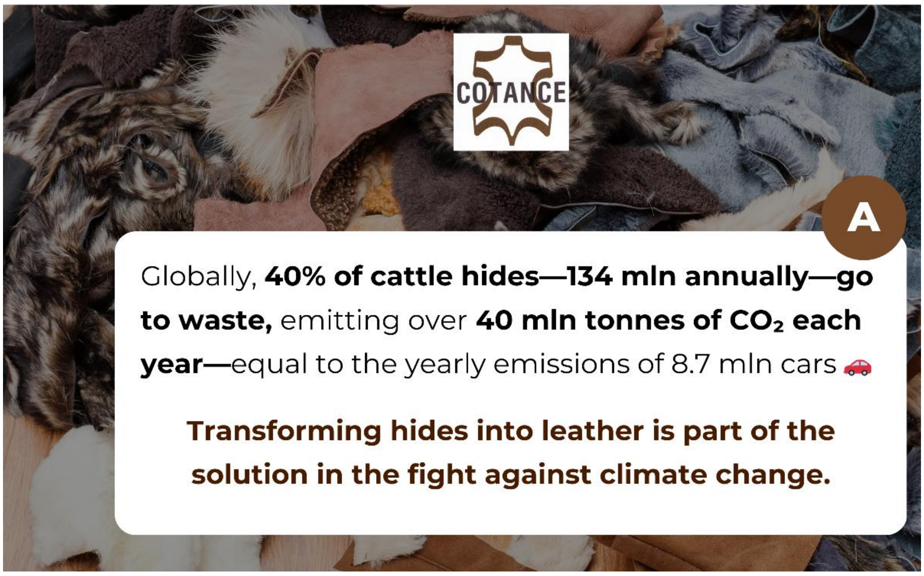
Problem: The more comprehensive the methodology was becoming, the more political choices had to be made. However, the PEF has not yet solved all methodological gaps and issues, including the issue of allocation in animal by-products.

Allocation rules determine how to share environmental impacts when multiple outputs arise from the same process. When it comes to leather, the question is how much of the livestock's environmental footprint (like methane emissions, feed, land use) should be "allocated" to meat, to milk and whether there should be any onto the hide or skin.

Leather left the PEF because the imposed allocation factors for hides and skins were not revised on time. The 3.5% economic allocation for cattle hides & skins - based on a study of 2009 - is definitely no longer up to date. For Sheep & Goatskins it is 1,6% - which does not reflect current status. For Pigskins it is 0%.

This means that leather starts its lifecycle with a heavy environmental burden, even before any processing begins — just because hides and skins are handled in PEF as if they were "products", i.e. as if they were made on demand.

Solution: Hides and skins of slaughtered animals are, however, by-products. They occur as a residue in the production of meat. They do not drive the process and will occur whether or not there is a demand for them or leather. Like waste, hides and skins leave the ecosystem in which they were generated for being integrated in another ecosystem, where they appear ex-novo. **Apply the same allocation as "waste"!**



Hides and skins exit the food and feed value chain and start a new lifecycle as leather in a different ecosystem "fashion and lifestyle" (Textiles) where they appear as if they came out of nowhere. Similar to what happens with crude oil, which is the raw material of synthetics.

Burdening hides and skins with an allocation of the environmental footprint of the animal makes the market shy away from leather although it is a natural and renewable resource and a circular economy material. Not transforming hides & skins to leather is definitely the worst environmental option, as rotting hides create GHGs.

In contrast, the absence of allocation from the generation of crude oil onto synthetic materials like faux "leather" results in comparatively lower reported environmental impacts in LCA assessments compared to natural materials, potentially influencing sustainability perceptions and decisions in the apparel and footwear industries.

🧵 ***PEF Upstream Allocation Comparison: Leather vs Plastic***

Material	***Source & Role***	**PEF Allocation**	**Explanation**
Leather	*Made from animal hides/skins, raised & slaughtered for the production of meat & milk for human consumption; by-product of livestock (meat & dairy industry)*	🚫 *3.5% of the cow's total environmental impact, 1.6% for sheep & goatskins & 0% for pigskins*	*Treated as if hides & skins were "products", or "co-products", like a steak or milk, even though animals are not raised for hides/skins.*
Plastic (PU/PVC)	*Made from fossil fuels (crude oil), generated through the fossilisation of plant and animal matter*	✅ *no allocation of the environmental impact of its generation*	Treated as if oil was spontaneously generated

Source: *COTANCE Table 2 Based on EC Annexes 1 & 2, 2021*

The European leather industry remains committed to science-based LCA methodologies that fairly reflect the environmental value of natural materials. We will keep demanding zero allocation for hides and skins, because:

- They do not drive upstream livestock production;
- They exit the food and feed ecosystem and begin a new lifecycle in the fashion and lifestyle sector;
- And most importantly, they become waste when demand fades — and should be treated as such - with zero-allocation.

Recognising this reality grants that sustainable materials like leather are given a fair place in the circular economy.

edited by

COTANCE

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If you want to go further:
Leather: Turning Waste into Climate Action | COTANCE November 2024 Newsletter
Environmental footprint, COTANCE | Article
Environmental Footprint Methods, European Commission | Article

IULTCS NEWSLETTER

IULTCS Newsleather
Stay curious, informed and connected

Edition 6, 2025

Welcome

This is the sixth edition of our scientific newsletter, dedicated to providing the latest updates on research, regulatory developments, technology, and standard methods in the leather industry.

NOTE: This newsletter is in English, Spanish and Portuguese. One version after the other. [LFJ Editor's note: For other language versions please visit www.iultcs.org].

In this issue, we feature an interview with Mr. Michael Costello, a board member of the ZDHC (Zero Discharge of Hazardous Chemicals) foundation. We are honored to have Mr. Michael Costello to collaborate with IULTCS. In today's interview we will focus only on chemical management and MRSL (Manufacturing Restricted Substances List); we will have another Newsleather with the ZDHC requirements for wastewater. For further information please consult the ZDHC website is: https://www.roadmaptozero.com

We extend our gratitude to Mr. Costello for his valuable collaboration on the IULTCS Newsleather.

Let me know if you'd like additional adjustments!

Please share your comments and suggestions to secretary@iultcs.org

Kind regards,
Dr. Luis A. Zugno, editor

IULTCS INTERVIEW

Lifeline: Michael Costello
Group Director of ESG (Environment, Social & Governance)

Michael is responsible for implementing Stahl's strategy of achieving ESG leadership in the industry and stimulating cooperation between its stakeholders. He presents the case of sustainable development to customers, brands, industry associations, NGO's and universities.

Aside from his role in Stahl, Michael serves as a board member of the ZDHC foundation and sits on the advisory board of the Renewable Carbon Initiative. He was a member of the Executive Committee of the Leather Working Group from 2017-2021. His focus is on raising awareness throughout the industry on sustainability-related topics like climate change mitigation, chemical management, Life Cycle Assessment, and supply chain transparency.

Michael joined Stahl USA in 1988 as a process chemist and subsequently occupied a variety of positions in the coatings and chemical processing industry. Having spent several years in commercial roles in Stahl and Momentive (formerly GE Silicones), Michael established the Stahl Polymers business unit in 2005 and served as its global director for ten years. He has held the ESG Group Director position since 2015.

Michael holds a BSc in Chemistry from University College, Dublin, Ireland, and an MBA from the University of Massachusetts, Boston.

See: https://www.linkedin.com/in/michael-costello-53782216

IULTCS Question 1: What is the mission of ZDHC? Are they a Non-For-Profit Organization?

ZDHC is a not for profit organization, based in Amsterdam, NL, focused on the global textile, apparel, leather and footwear value chains. The mission of ZDHC is toto achieve the highest standards for sustainable chemical management in these global value chains.

IULTCS Question 2: Why is it important for a tannery to be engaged with ZDHC?

Decisions are made in ZDHC that affect the tanning industry. It's better to be part of that decision making process, rather than having to react to decisions without preparation or discussion.

IULTCS Question 3: Please describe step by step what a tannery needs to do demonstrate conformance to the latest ZDHC MRSL as part of the LWG audit:

1. Ask their chemical supplier(s) for a ZDHC MRSL declaration for all the chemicals they supply.

2. Use this declaration from the chemical supplier as evidence of MRSL conformance during the LWG audit

3. Apply for access to ZDHC Gateway (Certified LWG tanneries can get free access to ZDHC Gateway (not membership). In the case of access to ZDHC Gateway, they can use this to demonstrate their level of conformance to the LWG auditor.

IULTCS Question 4: Explain the MRSL levels for the chemical supplier. Why this is important?

The ZDHC MRSL level 1, 2 and 3 in the ZDHC Gateway have been used since 2015 when the first MRSL was introduced. Chemicals are tested and verified against the latest MRSL (currently 3.1 is the latest version) by a third party. The chemical suppliers need to send chemical samples to an external accredited laboratory for testing.

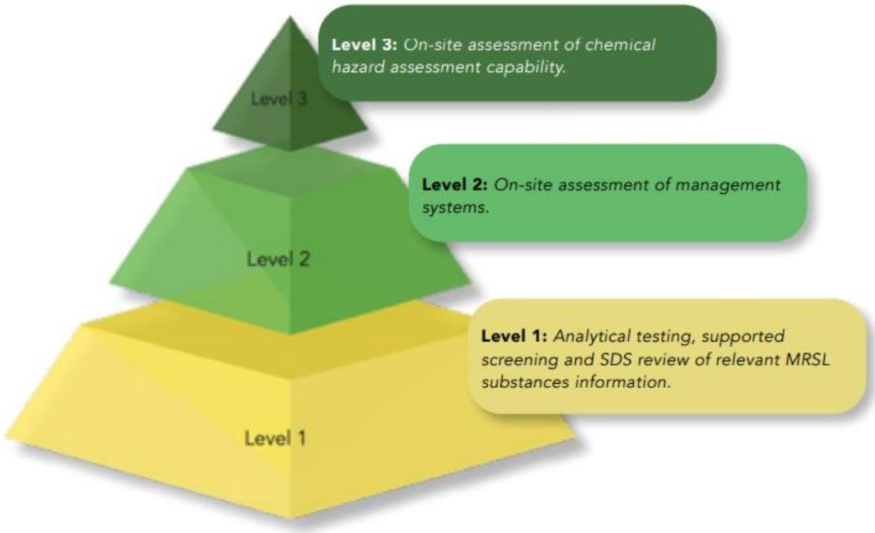

Figure 1: Diagram showing the basic requirements for the three levels. Source: https://downloads.roadmaptozero.com/input/ZDHC-MRSL-Conformance-Guidance

Level 1: is based on analytical testing of the chemical formulation for MRSL risks. An analytical test report from a ZDHC Approved Laboratory accreditted for ISO 17025 with proper scope is required as evidence of the ZDHC MRSL conformance for impurities.

Level 2: need evidence that Level 1 analytical evaluation of ZDHC MRSL is fulfilled. The audit includes on-site visit to the chemical formulation facility to evaluate the management sustems including environmental management systems (EMS), occupational helath and safety management system (OHSMS) and others.

Level 3: requires evidence that Level 1 and Level 2 have been achieved. There is a need for on-site assessement of of the chemical management system by the ZDHC Approved MRSL Certifier. The ZDHC MRSL list can be found here: https://mrsl-30.roadmaptozero.com/

The details of the certification can be found here: https://downloads.roadmaptozero.com/input/ZDHC-MRSL-ConformanceGuidance

Notes:

1) A chemical supplier that produces in different countries need to be certified in each country. If a specific product is made in different countries, it must be certified in each manufacturing country. It is best to cntact the thrid party supplier for these details.

2) The ZDHC certification has a validity period of two years

IULTCS Question 5: How the MRSL levels 1, 2 and 3 of the chemicals used in the tannery affect the LWG rating?

The more chemicals in the tannery's chemical inventory that are ZDHC Gateway Level 3 certified, the better the LWG score will be for that section of the audit. It is recommended that all the chemicals are at Level 3, since this means the supplier has also been audited.

IULTCS Question 6: Which ZDHC information is available to the chemical manufacturer, to the tannery and to the brands that buy from the tannery? What is this information available?

Chemical suppliers have access to ZDHC Gateway for their own formulations only. Tanneries who are ZDHC members or LWG rated tanneries have access to the chemical formulations in ZDHC Gateway. Brand members have access to ZDHC Gateway, indeed they use ZDHC Gateway as a buyer guide.

IULTCS Question 7: What is the relationship between the ZDHC and LWG? Explain the integration to avoid duplication of audits.

ZDHC and LWG are separate organizations with different missions, but there is collaboration on chemical management and MRSL conformance. The chemical management part of the LWG audit (originally introduced as the CMM – Chemical Management Module) requires tanneries to demonstrate the conformance of the chemicals they use to the latest ZDHC MRSL.

IULTCS Question 8: Looking forward, what are the upcoming changes on the ZDHC?

The goals in ZDHCs strategy for 2030 are clear: 100% of chemical formulations used in the ZDHC Community and 70% of chemical formulations used in the global industry to conform to the ZDHC MRSL. Progress towards these goals is monitored closely and ZDHC activities for the coming years will be focused on achieving them, and measuring the impact of achieving them.

IULTCS

IULTCS NEWSLETTER

IULTCS **Newsleather**

Stay curious, informed and connected

Edition 7, 2025

Welcome

This is the seventh edition of our scientific newsletter, dedicated to providing the latest updates on research, regulatory developments, technology, and standard methods in the leather industry.

This newsletter is available in English, Spanish, and Portuguese. On today's Newsleather the methods will be in English as they are technical terms.

This issue includes an update on the ISO/EN Official Leather Test Methods, and the methods developed by IULTCS that are not considered official standards. Dr. Giancarlo Lovato, the IULTCS ISO Committee Manager, explains how the Test Commissions function and how IULTCS, ISO, and CEN collaborate to create new standards for the leather industry.

We thank Dr. Lovato for his contribution to IULTCS and the leather industry.

Please share your comments and suggestions to secretary@iultcs.org

Kind regards,
Dr. Luis A. Zugno, editor

IULTCS/ISO Test Methods – Dr. Giancarlo Lovato

To advance and maintain analytical methods in line with technical progress, the IU Test Commissions were formed. These include the IUC (International Union Chemical Test Methods), IUP (International Union Physical Test Methods), and IUF (International Union Fastness Test Methods).

The IULTCS, through its IU Testing Commissions, supports the leather tanning industry globally by developing and publishing test methods specifically relevant to leather manufacture and usage. The IU Commissions' development of these test methods helps ensure that the leather industry does not have to meet performance standards of other materials that do not reflect the realities of working with leather.

Following agreements in 1990 and re-affirmed in 2005, the ISO (International Organization for Standardization) recognizes IULTCS as an International Standardizing Body.

ISO has assigned the responsibility for the development of leather test methods to IULTCS, and the resultant test method documents are published as joint IULTCS and ISO Standards.

An IULTCS ISO Committee Manager was established to coordinate the IU Testing Commissions' activities with ISO.

Since 2005, ISO has published all new joint IULTCS and ISO Standards. Many ISO member countries use these standards to form their own national standards.

The European Committee for Standardization (CEN), through the CEN/TC 289 Technical Committee "Leather", has adopted many IU/ISO Standards. The IU Commissions and the CEN/TC 289 Working Groups coordinate their efforts by holding joint technical meetings. This collaboration enables the publication of identical leather test methods for IULTCS, ISO, and EN Standards.

Below you will find the updated list of IULTCS methods (also available at the IULTCS website). The list has the IUC, IUF and IUP Test Methods classified as follows:

1) IUC, IUF and IUP Test Methods that are ISO and EN Standards. These methods can be purchased at: https://www.iso.org/store.html
2) IUC, IUF and IUP Test Methods that are only IULTCS Standards (in red color). They are available free at the IULTCS website: https://iultcs.org/iuc-iuf-iup-leather-test-methods-commissions/

For inquiries or comments regarding leather test methods, please reach out to the IULTCS ISO Committee Manager.

Dr. Giancarlo Lovato
IULTCS ISO Committee Manager
E-mail: office@iultcs.org

Legend for the Test Methods as of April 2025:

* The standards are available, but they are currently undergoing revision, and an update is in preparation

** The standards are new and currently undergoing development

*** The standards are the nearest textile to International Standard, recommended for use as the International Standard for Leather.

DIS (Draft International Standard) or FDIS (Final Draft International Standard) are in preparation and will be published shortly. These draft Standards can be obtained from your national Standards Organization but are not yet officially approved ISO Standards.

IULTCS - Chemical Test Methods for Leather			
UC Test method	**Method name**	**ISO Standard**	**EN Standard**
IUC 1 (1965)	General comments	-	-
IUC 2 (2023)	Position and preparation of specimens for testing *(same as IUP 2)*	**ISO 2418:2023**	**EN ISO 2418**
IUC 3 (2017)	Preparation of chemical test samples	**ISO 4044:2017**	**EN ISO 4044**
IUC 4 (2018)	Determination of matter soluble in dichloromethane and free fatty acid content	**ISO 4048:2018**	**EN ISO 4048**
IUC 5 (2005)	Determination of volatile matter	**ISO 4684:2005**	**EN ISO 4684**
IUC 6 (2018)	Determination of water-soluble matter, water soluble inorganic matter and water-soluble organic matter	**ISO 4098:2018**	**EN ISO 4098**
IUC 7 (1977)	Determination of sulphated total ash and sulphated water insoluble ash	**ISO 4047:1977**	**EN ISO 4047**
IUC 8 (2018)	Determination of chromic oxide content Part 1: Quantification by titration	**ISO 5398-1:2018**	**EN ISO 5398-1**
IUC 8-2 (2009)	Determination of chromic oxide content Part 2: Quantification by colorimetric determination	**ISO 5398-2:2009**	**EN ISO 5398-2**
IUC 8-3 (2018)	Determination of chromic oxide content Part 3: Quantification by atomic absorption spectrometry	**ISO 5398-3:2018**	**EN ISO 5398-3**
IUC 8-4 (2018)	Determination of chromic oxide content Part 4: Quantification by inductively coupled plasma (ICP-OES)	**ISO 5398-4:2018**	**EN ISO 5398-4**
IUC 9 (1984)	Determination of water-soluble magnesium salts	-	-
IUC 10 (1984)	Determination of nitrogen and hide substance	**ISO 5397:1984**	-
IUC 11 (2018)	Determination of pH and difference figure	**ISO 4045:2018**	**EN ISO 4045**
IUC 13 (1975)	Determination of zirconium	-	-
IUC 15 (1973)	Determination of phosphorus	-	-
IUC 16 (1969)	Determination of aluminum	-	-
IUC 17 (1980)	Determination of hydroxyproline in materials containing collagen	-	-
***IUC 18-1** (2017)	Determination of hexavalent chromium content – Part 1: Colorimetric method	***ISO 17075-1:2017**	***EN ISO 17075-1**
***IUC 18-2** (2017)	Determination of hexavalent chromium content – Part 2: Ion chromatographic method	***ISO 17075-2:2017**	***EN ISO 17075-2**
IUC 19-1 (2021)	Determination of formaldehyde content in leather Part 1: Quantification by HPLC	**ISO 17226-1:2021**	**EN ISO 17226-1**
IUC 19-2 (2018)	Determination of formaldehyde content in leather Part 2: Quantification by colorimetric analysis	**ISO 17226-2:2018**	**EN ISO 17226-2**
IUC 19-3 (2011)	Determination of formaldehyde content in leather Part 3: Formaldehyde emissions from leather	**ISO 17226-3:2011**	**EN ISO 17226-3**
IUC 20-1 (2024)	Chemical tests for the determination of certain azo colorants in dyed leathers Part 1: Determination of certain aromatic amines derived from azo colorants	**ISO 17234-1:2024**	**EN ISO 17234-1**
IUC 20-2 (2011)	Chemical tests for the determination of certain azo colorants in dyed leathers Part 2: Determination of 4-aminoazobenzene derived from azo colorants	**ISO 17234-2:2011**	**EN ISO 17234-2**

The IULTCS official methods of analysis for leather (IUC, IUP and IUF), including the equivalent ISO and EN Standards

IUC 21 (2003) (now included in IUC 20-1)	**Method for the detection of certain azo colorants in dyestuff mixtures.** (Method Annexed in the new revision IUC 20-1, ISO 17234-1:2024)	-	-
IUC 22 (2003)	**Determination of aluminium oxide content of aluminium tanning agents**	-	-
IUC 24 (2003)	**Determination of basicity of aluminium tanning agents.**	-	-
***IUC 25** (2015)	Determination of tetra chlorophenol-, trichlorophenol-, dichlorophenol-, mono chlorophenol-isomers and pentachlorophenol content	***ISO 17070:2015**	***EN ISO 17070**
IUC 26 (2021)	Determination of free-formaldehyde content in leather processing chemicals	**ISO 27587:2021**	**EN ISO 27587**
***IUC 27-1** (2019)	Chemical determination of metal content. – Part 1: Extractable metals	***ISO 17072-1:2019**	***EN ISO 17072-1**
IUC 27-2 (2022)	Chemical determination of metal content. – Part 2: Total metal content	**ISO 17072-2:2022**	**EN ISO 17072-2**
IUC 28-1 (2023)	Determination of ethoxylated alkylphenols in leather Part 1: Direct method	**ISO 18218-1:2023**	**EN ISO 18218-1**
IUC 28-2 (2019)	Determination of ethoxylated alkylphenols in leather Part 2: Indirect method	**ISO 18218-2:2019**	**EN ISO 18218-2**
IUC 29-1 (2020)	Determination of preservative content (TCMTB-OPP MK-OIT) in leather – Part 1: Acetonitrile extraction method	**ISO 13365-1:2020**	**EN ISO 13365-1**
IUC 29-2 (2020)	Determination of preservative content (TCMTB-OPP CMK-OIT) in leather– Part 2: Artificial perspiration extraction method	**ISO 13365-2:2020**	**EN ISO 13365-2**
IUC 30-1 (2021)	Leather - Chemical determination of chlorinated hydrocarbons in leather – Part 1: Chromatographic method for short chain chlorinated paraffins (SCCP)	**ISO 18219-1:2021**	**EN ISO 18219-1**
IUC 30-2 (2021)	Leather - Chemical determination of chlorinated hydrocarbons in leather – Part 2: Chromatographic method for middle chain chlorinated paraffins (MCCP)	**ISO 18219-2:2021**	**EN ISO 18219-2**
IUC 32 (2020)	Quantitative analysis of tanning agents by filter method	**ISO 14088:2020**	**EN ISO 14088**
IUC 33 (2013)	Leather - Determination of tan content of synthetic tanning agents	**ISO 17489:2013**	**EN ISO 17489**
IUC 34 (2016)	Leather - Determination of N-methyl pyrrolidone in leather	**ISO 19070:2016**	**EN ISO 19070**
IUC 35 (2016)	Leather - Determination of Cr(VI) and its reductive potential in leather chemicals	**ISO 19071:2016**	**EN ISO 19071**
IUC 36 (2023)	Leather - Guidelines for testing critical chemicals in leather	**ISO 20137:2023**	**EN ISO 20137**
IUC 37 (2020)	Leather - Determination of degradability by micro-organisms	**ISO 20136:2020**	**EN ISO 20136**
IUC 38 (2019)	Leather - Determination of pesticide residues content in leather	**ISO 22517:2019**	**EN ISO 22517**
IUC 39-1 (2023)	Leather - Per- and polyfluoroalkyl substances — Part 1: Determination of non-volatile compounds by extraction method using liquid chromatography	**ISO 23702-1:2023**	**EN ISO 23702-1**
****IUC 40** (2024)	Leather – Chemical analysis – Determination of glutaraldehyde content	****ISO/DIS 25202:2024**	****prEN ISO/DIS 25202**
IUC 41(2018)	Leather - Determination of hexavalent chromium content – Pre-ageing for chemical determination of hexavalent chromium	**ISO 10195:2018**	**EN ISO 10195**
IUC 42 (2023)	Leather – Determination of total content of certain bisphenols	**ISO 11936:2023**	**EN ISO 11936**
-	Determination of total silicon content – Reduced molybdosilicate spectrometric method	**ISO 5400:1984**	-
-	Determination of organotin compounds in leather by GC/MS method (**Project transferred to ISO/TC 216 Footwear**)	**ISO/TS 16179:2012** (Footwear method)	**CEN ISO/TS 16179**

IULTCS - Chemical Test Methods for Leather Chemicals			
IUC Test Method	**Method name**	**ISO Standard**	**EN Standard**
IUC 442 (2024)	Chemicals for the leather tanning industry – Determination of total content of certain bisphenols	**ISO 21135:2024**	**EN ISO 21135**
****IUC 443** (2025)	Chemicals for the leather tanning industry – Determination of melamine	****ISO/AWI 25172:2025**	****EN ISO/AWI 25172**
IUC 444 (2025)	Chemicals for the leather tanning industry – Determination of cyclosiloxanes	**ISO 23649:2025**	**EN ISO 23649**

If an IULTCS test method exists for leather (e.g. IUC xx), then the leather chemical test method number has the format 4xx.

IULTCS – Physical Test Methods for Leather			
IUP Test method	**Method name**	**ISO Standard**	**EN Standard**
IUP 1 (now included in IUP 2)	Sample preparation *(Sample preparation IUP 1 included in the new IUP 2:2023)*	-	-
IUP 2 (2023)	Position and preparation of specimens for testing *(same as IUC 2)*	**ISO 2418:2023**	**EN ISO 2418**
IUP 3 (2024)	Specimen and test piece conditioning	**ISO 2419:2024**	**EN ISO 2419**
IUP 4 (2016)	Measurement of thickness	**ISO 2589:2016**	**EN ISO 2589**
IUP 5 (2017)	Measurement of apparent density	**ISO 2420:2017**	**EN ISO 2420**
IUP 6 (2020)	Measurement of tensile strength and percentage elongation	**ISO 3376:2020**	**EN ISO 3376**
***IUP 7** (2016)	Measurement of static absorption of water	***ISO 2417:2016**	***EN ISO 2417**
***IUP 8** (2016)	Measurement of tear load – Double edge tear	***ISO 3377-2:2016**	***EN ISO 3377-2**
IUP 9 (2024)	Measurement of distension and strength of grain by the ball burst test	**ISO 3379:2024**	**EN ISO 3379**
***IUP 10-1** (2011)	Water resistance of flexible leather. Part 1: Linear compression method (Penetrometer)	***ISO 5403-1:2011**	***EN ISO 5403-1**
***IUP 10-2** (2011)	Water resistance of flexible leather. Part 2: Angular compression method (Maeser)	***ISO 5403-2:2011**	***EN ISO 5403-2**
IUP 11 (2011)	Measurement of water resistance of heavy leather	**ISO 5404:2011**	**EN ISO 5404**
IUP 12 (2002)	Measurement of resistance to grain cracking and the grain crack index	**ISO 3378:2002**	**EN ISO 3378**
IUP 13 (1961)	Measurement of two-dimensional extension	-	-
IUP 14 (1960)	Measurement of waterproofness of gloving leathers	-	-
IUP 15 (2023)	Determination of water vapor permeability	**ISO 14268:2023**	**EN ISO 14268**
IUP 16 (2015)	Measurement of shrinkage temperature up to 100 °C	**ISO 3380:2015**	**EN ISO 3380**
IUP 17 (1966)	Assessment of the resistance of air-dry insole leathers to heat	-	-
IUP 18 (1969)	Resistance of air-dry lining leathers to heat	-	-
IUP 19 (1969)	Resistance of air-dry upper leather to heat	-	-
IUP 20 (2022)	Determination of flex resistance. Part 1: Flexometer method	**ISO 5402-1:2022**	**EN ISO 5402-1**
IUP 21 (1963)	Measurement of set in lasting	-	-
IUP 22 (1963)	Assessment of scuff damage by using the viewing box	-	-
IUP 23 (1963)	Measurement of scuff damage	-	-
IUP 24 (1964)	Measurement of surface shrinkage by immersion in boiling water	-	-
IUP 26 (1993)	Measurement of resistance to abrasion of heavy leather	-	-
IUP 28 (1969)	Measurement of the resistance to bending of heavy leather	-	-
IUP 29 (2017)	Measurement of cold crack temperature of surface coatings	**ISO 17233:2017**	**EN ISO 17233**
IUP 30 (1983)	Measurement of water vapor absorption and desorption (See IUP 42)	-	-
IUP 32 (2014)	Measurement of area	**ISO 11646:2014**	**EN ISO 11646**
IUP 35 (2002)	Determination of the dimensional stability of leather (Old title: Measurement of dry heat resistance of leather)	**ISO 17227:2002**	**EN ISO 17227**
IUP 36 (2015)	Measurement of leather softness	**ISO 17235:2015**	**EN ISO 17235**
IUP 37 (2017)	Measurement of water repellency of garment leather	**ISO 17231:2017**	**EN ISO 17231**
***IUP 38** (2017)	Measurement of heat resistance of patent leather	***ISO 17232:2017**	***EN ISO 17232**
IUP 39-2 (2015)	Determination of flex resistance. Part 2: Vamp flex method	**ISO 5402-2:2015**	**EN ISO 5402-2**
IUP 40-1 (2011)	Measurement of tear load – Single edge tear	**ISO 3377-1:2011**	**EN ISO 3377-1**
IUP 41 (2011)	Measurement of surface coating thickness	**ISO 17186:2011**	**EN ISO 17186**
IUP 42 (2016)	Measurement of water vapor absorption	**ISO 17229:2016**	**EN ISO 17229**
***IUP 43** (2016)	Measurement of extension set	***ISO 17236:2016**	***EN ISO 17236**
IUP 44 (2019)	Measurement of stitch tear resistance	**ISO 23910:2019**	**EN ISO 23910**
IUP 45 (2006)	Measurement of water penetration pressure	**ISO 17230:2006**	**EN ISO 17230**
IUP 46 (2006)	Measurement of fogging characteristics	**ISO 17071:2006**	**EN ISO 17071**
IUP 47 (2006)	Measurement of resistance to horizontal spread of flame	**ISO 17074:2006**	**EN ISO 17074**
IUP 48-1 (2020)	Measurement of abrasion resistance. Part 1: Taber method	**ISO 17076-1:2020**	**EN ISO 17076-1**
IUP 48-2 (2011)	Measurement of abrasion resistance. Part 2: Martindale ball plate method	**ISO 17076-2:2011**	**EN ISO 17076-2**
IUP 49	Measurement of bagginess, creep and relaxation	-	**CEN/TS 14689:2006**
IUP 50	*Free (original document changed to IUP 53-2)*	-	-
IUP 51 (Draft: 2002)	Measurement of Surface Friction	-	-
IUP 52 (Draft: 2002)	Measurement of Compressibility	-	-
***IUP 53-1** (2019)	Determination of soiling. Part 1: Martindale method	***ISO 26082-1:2019**	***EN ISO 26082-1**
IUP 53-2 (2012)	Determination of soiling. Part 2: Tumbling method	**ISO 26082-2:2012**	**EN ISO 26082-2**
IUP 54 (2022)	Determination of flexural properties	**ISO 14087:2022**	**EN ISO 14087**
IUP 55 (2021)	Determination of dimensional change	**ISO 17130:2021**	**EN ISO 17130**
IUP 56 (2020)	Identification of leather with microscopy	**ISO 17131:2020**	**EN ISO 17131**

IULTCS – Physical Test Methods for Leather			
IUP Test method	**Method name**	**ISO Standard**	**EN Standard**
IUP 57 (2015)	Determination of water absorption by capillary action(wicking)	**ISO 19074:2015**	**EN ISO 19074**
IUP 58 (2023)	Measurement of leather surface – Electronic techniques	**ISO 19076:2023**	**EN ISO 19076**

IULTCS – Fastness Test Methods for Leather (including other test methods)			
IUF Test method	**Method name**	**ISO Standard**	**EN Standard**
IUF 105 (1966)	Numbering code for fastness tests	-	-
IUF 110 (2014)	Leather – Sampling – Number of items for a gross sample	**ISO 2588:2014**	**EN ISO 2588**
IUF 120 (2022)	General principles of color fastness testing of leather	**ISO 7906:2022**	**EN ISO 7906**
IUF 131 (1966)	Grey scale for assessing change in color	*****ISO 105-A02:1993**	*****EN ISO 105-A02**
IUF 132 (1966)	Grey scale for assessing staining	*****ISO 105-A03:2019**	*****EN ISO 105-A03**
IUF 151 (1975)	Preparation of storable standard chrome grain leather for dyeing	-	-
IUF 201 (1966)	Approximate determination of the solubility of leather dyes	-	-
IUF 202 (1966)	Fastness to acid of dye solutions	-	-
IUF 203 (1966)	Stability to acid of dye solutions	-	-
IUF 205 (1972)	Stability to hardness of dye solutions	-	-
IUF 401 (1972)	Color fastness of leather to light: Daylight	*****ISO 105-B01:2014**	*****EN ISO 105-B01**
IUF 402 (1975)	Color fastness of leather to light: Xenon lamp	*****ISO 105-B02:2014**	*****EN ISO 105-B02**
***IUF 412** (2015)	Change of color with accelerated ageing.	***ISO 17228:2015**	***EN ISO 17228**
IUF 420 (1998)	Color fastness to water spotting	**ISO 15700:1998**	**EN ISO 15700**
***IUF 421** (2012)	Color fastness to water	***ISO 11642:2012**	***EN ISO 11642**
****IUF 422** (2024)	Color fastness to sea water	****ISO/DIS 25089:2024**	****prEN ISO/DIS25089**
IUF 423 (1998)	Color fastness to mild washing	**ISO 15703:1998**	**EN ISO 15703**
***IUF 426** (2012)	Color fastness to perspiration	***ISO 11641:2012**	***EN ISO 11641**
IUF 427 (2024)	Color fastness to saliva	**ISO 20701:2024**	**EN ISO 20701**
****IUF 428** (2024)	Color fastness to hydroalcoholic mixtures	****ISO/DIS 7979:2024**	****prEN ISO/DIS 7979**
IUF 434 (2009)	Color fastness of small samples to solvents	**ISO 11643:2009**	**EN ISO 11643**
IUF 435 (1998)	Color fastness to machine washing	**ISO 15702:1998**	**EN ISO 15702**
IUF 441 (1972)	Color fastness in respect of staining raw crepe rubber	-	-
IUF 442 (2022)	Color fastness to migration into polymeric materials	**ISO 15701:2022**	**EN ISO 15701**
IUF 450 (2018)	Color fastness to cycles of to-and-fro rubbing	**ISO 11640:2018**	**EN ISO 11640**
IUF 452 (2024)	Color fastness to crocking	**ISO 20433:2024**	**EN ISO 20433**
IUF 454 (1975)	Fastness to buffing of dyed leather	-	-
IUF 458 (1984)	Color fastness of leather to ironing	-	-
IUF 470 (2022)	Leather – Test for adhesion of finish	**ISO 11644:2022**	**EN ISO 11644**
IUF 472 (2013)	Leather – Determination of surface reflection	**ISO 17502:2013**	**EN ISO 17502**
***IUF 474** (2019)	Leather – Measuring color and color difference of finished leather	***ISO 22700:2019**	***EN ISO 22700**

The following textile fastness Standards do not have equivalent IU leather test methods but are recommended for use as theInternational Standard for leather.

-	Instrumental assessment of the degree of staining of adjacent fabrics	**ISO 105-A04:1989**	**EN ISO 105-A04**
-	Instrumental assessment for change in color for grey scale	**ISO 105-A05:1996**	**EN ISO 105-A05**
-	Color fastness & ageing to artificial light at high temperatures: Xenon	**ISO 105-B06:2020**	**EN ISO 105-B06**
-	Oil repellency – Hydrocarbon resistance test	**ISO 14419:2010**	**EN ISO 14419**

IULTCS NEWSLETTER

Newsleather
Stay curious, informed and connected

Edition 8, 2025

Welcome

This is the eighth edition of our scientific newsletter, dedicated to providing the latest updates on research, regulatory developments, technology, and standard methods in the leather industry.

NOTE: This newsletter is in English, Spanish and Portuguese. One version after the other. [LFJ Editor's note: For other language versions please visit www.iultcs.org].

In this issue, we feature an interview with Mr. Paulo Caye, a tanner, and Chief Executive Officer (CEO) of Cuero Centro in León, Mexico.

It is a great honor for IULTCS to have the collaboration of Mr. Paulo in a very important subject: the challenges and opportunities of the wet blue leather production in León, Mexico. León is the most important automotive center in the planet, and we are also grateful that our colleagues of AQTCL that will host the 2027 IULTCS Congress in León.

We appreciate Mr. Paulo's collaboration with IULTCS' Newsleather.

Please subscribe here: https://bit.ly/3NsXNeL and share your comments to secretary@iultcs.org

Kind regards,
Dr. Luis A. Zugno, editor

IULTCS INTERVIEW

Lifeline: Paulo Caye
CEO of Cuero Centro, León, México

Paulo has degrees in Leather Chemistry at SENAI, Brazil; Industrial Chemistry at UNISC, Brazil and degree in Financial Administration from the University of State of Guanajuato, Mexico.

Paulo has been the CEO of Cuero Centro in León, Mexico since 2018. His previous experiences include working as COO at Cueromex, León, Mexico from 2017 to 2018, and from 1998 to 2002. Paulo held positions at Lanxess (formerly Bayer) from 2002 to 2016, serving as Regional Manager in Central and North America and Director of the Leather Business in Brazil.

Cuero Centro (Leather Center) in León, Mexico, was established in 1989 as a vegetable sole tannery. In 1993, it was converted to wet blue production, and it is currently the largest tanning plant in Mexico. Cuero Centro ensures top-quality products and compliance through standardized processes, LWG Gold certification, and advanced technology.
https://www.cuerocentro.com.mx/

IULTCS Question 1: Paulo, please give us an overview of the current leather production in Mexico

The automotive and shoe industries are key segments for leather in Mexico. Automotive leather manufacturing relevance significantly increased in the past years with the arrival and settlement of important players from different parts of the world. But unfortunately, production levels have decreased due to the leather content reduction strategy implemented by the major Original Equipment Manufacturers (OEMs) in new car models, replacing leather with synthetic materials. Similarly, leather shoe production fell due to synthetic replacements and increased imports from China to Mexico and USA. Currently, production levels are at 60-70%, with capacity available for new projects.

Some statistics:

- The Mexican tanning industry processes about 12 million cow hides/year, being 75% Mexican and 25% imported (mostly from the USA)

- Mexico exports about 1.5 million wet blue leathers - The leather production is estimated to be 50% auto, 40% shoe and 10% others

IULTCS Question 2: Why is León considered the World's Automotive Leather capital?

León leads the world in automotive leather production, with nearly all relevant automotive leather manufacturers in the world have established operations there or are planning to do so. Mexico has become a key hub for North American automotive production with the establishment of several automotive clusters, particularly in León due to its central location. The city is close to 10 OEM plants, supported by numerous Tier 1 and 2 plants, and offers easy access to other automotive clusters in Central and Northern Mexico and the USA.

IULTCS Question 3: León has a big problem with water availability, but despite that the leather industry flourishes very well. What is planned to solve this problem?

Just like many other parts of the world, water scarcity in Mexico is increasing, therefore is a big problem that needs strong attention. Although the leather industry uses only 2% of the city's water, the leather industry has been working closely and responsibly with the local authorities to find sustainable solutions. Tanning processes are restricted to areas with connectivity to the main city water treatment plant. All the effluents from tanning are pretreated and then mixed with effluents from other industries as well from housing to complete the treatment, obtaining water with a permissible quality that allows it to be reused for irrigation purposes and by industry. Every year the quality of this treated water is improving, allowing more tanneries to "buy it back" and use it in more processes, reducing the usage of "fresh water" necessary for human consumption. For example, last year the tanneries increased the consumption of this treated water by 20%. An ongoing project expected to be concluded shortly, aims to pump this treated water into a big dam, then using nanotechnology and natural filtering to make it potable. This initiative will ensure that all water used by tanneries in León is treated and reused efficiently.

IULTCS Question 4: Cuero Centro is the largest tanning plant in Mexico. Which are the biggest challenges you face day by day in leather production?

Water management is a significant challenge, and we aim to lower water consumption per kg of hide, reduce effluent contamination, and reuse more water from the city treatment plant while ensuring strict quality control. Recruiting and retaining skilled personnel (technical and operators) is another challenge, as younger generations prefer industries like the automotive industry over tanning. We focus on attracting, training, and retaining talent and increasing automation in machinery and systems in our facilities to simplify processes. Additionally, we work to obtain and maintain necessary certifications, with increasing importance of traceability, restricted substances, and social responsibility.

Figure 1: Wet blue produced at Cuero Centro

IULTCS Question 5: How do you define the properties of the wet blue produced by Cuero Centro? How many tannage formulas you have?

Our main core competence is customer service through customized processes. We ensure timely delivery of Wet Blue or Free Of Chrome (FOC) products with specific properties tailored to raw materials. While we aim for process standardization, each customer requires different raw material in terms of origin country, curing, fleshing, gender, etc., as well tanning process (full substance, lime splitting, chrome, aldehyde, zeolite, different list of restricted substances and specific properties goals (tightness, yield, etc.)). This complexity makes us set our production into more than 10 different types of tanning processes. Cuero Centro produces wet blue or FOC leather and operates as a contractor (maquila), with a total production of 30,000 cow leathers per week.

IULTCS Question 6: Today a tannery must be compliant with several regulatory bodies and certifications. How does Cuero Centro address these challenges?

Compliance is essential, and we must provide the necessary resources to meet various requirements. One team handles regulatory compliance; another manages certifications. Though they operate independently, they coordinate closely and use external consultants for training and expert oversight. Definitively this has an important impact on our costs that frequently customers do not recognize, therefore it is important that the leather industry work together with the customers to unify as much as possible the certifications and make a clear distinction between those companies that are certified and not.

IULTCS Question 7: Today wet blue has many RSL requirements. To comply with these requirements the chemicals must be on the MRSL 3.0 list, and leather must be tested. How big is this problem? How big is the cost of maintaining these requirements yearly?

This is a huge problem. First, maintain an updated matrix with all RSLs, which often have different analysis methods for the same substance, so the first call is to try to unify or correlate these different methods. Next, address misinformation when customers include substances in their RSL without clear reason, then it needs to be discussed, and most of the time the customer recognizes that they just copied a requirement from another list but in fact they do not need it. Ensure that chemicals used in our processes do not contain banned substances, using only chemicals from ZHDC MRSL 3.0, which can hinder new suppliers, especially smaller ones unable to afford registration. And finally analyzing regularly our different types of products according to this matrix of restricted substances in certified laboratories, that must be done in overseas laboratories because most of the analysis methods required are not available or certified at Mexican laboratories. To sum up, the whole cost is very high and increasing with more substances and parameters being added to these lists, together with less certified laboratories available to check them.

IULTCS Question 8: How you characterize the local hides (Mexican) compared with the American hides? Properties, grain quality, size, thickness (do you have a lot of zebus?)

Mexican hides typically come from crossbred European and Zebu cattle, usually slaughtered at around 2 years old. They average 42-46 sqft in size and weigh 29-32 kg (fresh), with wet blue weighing 19-21 kg. These cattle are grass-fed before spending about 4 months in feedlots before slaughter, leading to hides with natural defects like scratches and ticks that are mostly healed. The leather has good structure and thickness, being suitable for heavy and tight articles. Due to disease control laws, cattle crossing states must be branded, so hides often bear one or more brands. Our suppliers are advanced slaughterhouses with very good technology and traceability, ensuring fleshed hides are delivered fresh and refrigerated, minimizing issues like cuts, holes, or poor conservation.

IULTCS Question 9: Many times, we hear that Mexico could be the big producer of wet blue for the world. Today the United States exports about 20 million salted hides. If salt becomes restricted for curing, Mexico is the only country with capacity and distance to process the fresh hides. What is your opinion about this? Is it feasible?

In the short-term, Mexico is likely to process and export more leathers made with American hides due to its advantages. These include easier access to chemicals, machine spare parts, and better solid and liquid waste management solutions within our leather cluster. Although workforce availability is a challenge in Mexico too, we have more and better-trained workers than the USA. I would say that the most critical point right now is the high cost of freight from the USA packers to Mexico tanneries. We have been working on many alternatives to improve logistics, including for the fresh hides, and the results have been very positive. There is still work to be done either with packers in the USA and customers overseas to put all costs and advantages together, including quality costs for conservation, environmental costs like the usage of salt, and those hidden costs that packers will avoid sending by fresh hides.

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