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

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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

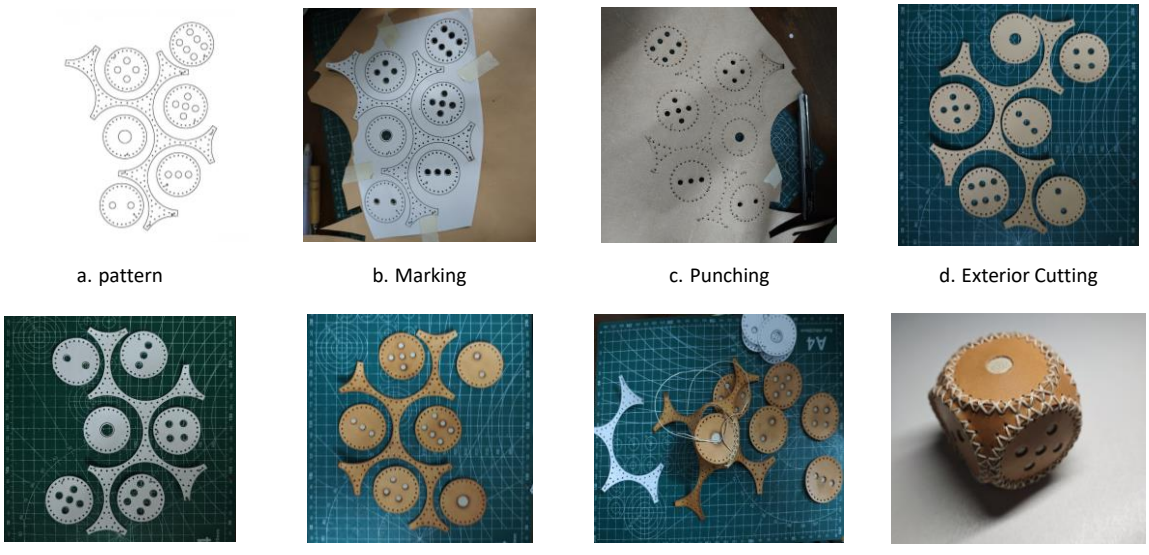
well as crafting techniques. The cutting and sewing process incorporates digital scanning technology for computer-aided pattern development, followed by precision cutting in accordance with digitally generated design specifications, culminating in manual stitching procedures. The crafting techniques 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.

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