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A Comparative Study of the Durability and Quality of Different Leathers in Terms of Service Life and Resistance to Damage

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Abstract

This study aimed to comparatively evaluate the durability and performance characteristics of various leather types, including natural leathers (bovine, caprine, ostrich), artificial leathers (PU, PVC), and synthetic leather, in terms of service life and damage resistance. The experimental and causal–comparative research focused on analyzing the functional properties of the materials. Samples were prepared according to standard procedures and subjected to tests for abrasion resistance, tensile strength, moisture permeability, colorfastness, and chemical resistance. Testing was conducted in compliance with international standards (ASTM, ISIRI). The independent variable was leather type, with dependent variables being test outcomes. Data were collected under controlled laboratory conditions and analyzed using descriptive and inferential statistics (t-test, ANOVA).
Findings indicated that ostrich leather exhibited superior performance across all tests, offering the highest durability and mechanical/chemical resistance. Bovine and caprine leathers also demonstrated acceptable performance. Artificial leathers (PU, PVC), despite cost benefits, showed deficiencies in moisture permeability and color stability, limiting their suitability for demanding applications. Synthetic leather, though mechanically weaker, was identified as an eco-friendly alternative due to its sustainable production and reduced environmental impact. Statistical analysis confirmed significant differences between natural and artificial leathers across all evaluated properties, highlighting the preference for natural leathers in high-end and industrial applications.

Keywords: Leather durability and quality, leather service life, leather resistance, sustainability.

1. Introduction

Leather, as one of the oldest and most widely used natural materials in the production of clothing, bags, footwear, furniture, and luxury goods, has always held a prominent position

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across various industries. The extensive use of leather is attributed not only to its aesthetic appeal and distinctive tactile properties but also to its high durability and resistance to environmental factors and wear. Nevertheless, not all leathers possess the same level of quality and durability, and several factors including the type of animal hide, tanning process, maintenance practices, and usage intensity can significantly affect their service life and resistance (Pancapalaga et al., 2021).

In recent years, increasing attention has been directed toward the reuse of leather waste and the optimization of production processes for both natural and artificial leathers. With the expansion of footwear, apparel, and furniture industries, demand for leathers with high durability, substantial mechanical resistance, and extended service life has increased considerably (Hossain et al., 2021). Concurrently, rising environmental awareness and the need to reduce industrial waste have encouraged researchers to explore solutions for recycling leather waste and enhancing the physical and chemical properties of produced leathers (Bahadirov et al., 2024).

Numerous studies have shown that incorporating leather waste into polymer matrices such as polyester, polyurethane, and elastomers not only improves tensile strength, hardness, and abrasion resistance, but also enhances thermal properties and durability under environmental conditions such as moisture, heat, and chemical exposure (Lei et al., 2023). Moreover, selecting appropriate tanning methods, modifying polymer structures with bio-based materials, and optimizing production process parameters have been shown to significantly influence leather performance and sustainability (Dapper et al., 2025).

Based on this background, the present study aims to comparatively evaluate the durability and quality of various types of leather in terms of service life and resistance to damage by providing a deeper analysis of the mechanical and environmental properties of different leathers. Through causal–comparative assessment, this research seeks to identify effective criteria for selecting and developing high-performance leathers for diverse industrial applications.

2. Research Background

Domestic Studies

Radmard et al. (1402) conducted a study entitled “Investigation of the Effect of Adding Processed Leather Waste on the Mechanical Properties of Leather–Polyester Composites.” In this research, chrome-tanned leather waste powder was used as an additive in polyester-based polymer composites. Part of the chromium present in the leather was extracted through an alkaline hydrolysis process, and the modified leather was employed to improve composite mechanical properties. Tensile strength and elongation tests showed that the use of processed leather waste enhanced the mechanical properties of the produced composites while simultaneously contributing to effective recycling of leather industry waste.

Zamani and Shokrieh (1402), in a study entitled “Investigation of the Effects of Curing Time and Temperature on the Mechanical Properties and Thermal Degradation of PVC-Based Artificial Leather,” examined the influence of curing time and temperature on the mechanical and thermal degradation behavior of PVC-based artificial leather. Artificial leather produced via knifecoating was cured under various conditions, and colorimetric, tensile, and thermal analyses were performed. Results indicated that curing at 190 °C improved mechanical properties due to enhanced plasticizer penetration into PVC chains. Increasing curing time initially increased mechanical strength but subsequently caused degradation due to thermal damage. The study demonstrated that precise optimization of curing conditions can significantly enhance mechanical properties without the need for special additives.

Shabani et al. (1386), in a study entitled “Investigation of the Effect of Adding Leather Fibers on Vulcanization Characteristics and Physical–Mechanical Properties of Elastomeric

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Blends," evaluated the effect of incorporating leather fibers into elastomers such as CR, NBR, and EPDM. Findings revealed that leather fiber addition significantly altered final blend properties, including hardness, density, and abrasion resistance, without negatively affecting processability. Additionally, incorporating leather fibers into NBR matrices enhanced mechanical strength depending on the curing system. These results highlight the high potential of leather fibers as reinforcing agents in polymer blends.

International Studies

Nazir et al. (2025), in a study entitled "Upcycling Leather Waste: The Effect of Leather Type and Aspect Ratio on the Performance of Thermoplastic Polyurethane Composites," evaluated the recycling and upgrading potential of leather waste by incorporating it into thermoplastic polyurethane (TPU). Leathers with different tanning methods and particle sizes were added to TPU matrices at weight fractions of 5–30%. Thermal, mechanical, morphological, abrasion, and tear tests showed that composite performance was significantly influenced by leather type and particle aspect ratio. The highest performance was observed for "wet blue" leather waste with an aspect ratio of 61, increasing the Young's modulus to 305 MPa. These results emphasize the importance of particle size control and leather type selection in producing durable and sustainable composites.

Xue et al. (2024), in a study entitled "Waterborne Polyurethane Synthesized for Leather with Excellent Wear and Hydrolysis Resistance Enabled by Bio-Based Poly (Trimethylene Carbonate) and L-Lysine Diisocyanate," investigated the synthesis and performance of bio-based waterborne polyurethanes (BWPU) for artificial leather applications. Using bio-based poly(trimethylene carbonate) diol and L-lysine diisocyanate, a series of linear and crosslinked polyurethanes were produced. Results showed that crosslinked films (CBWPU-1%) exhibited high tensile strength (41.5 MPa), remarkable toughness (131 $MJ \cdot m^{-3}$), and exceptional hydrolysis resistance (only 1.4% weight loss after 35 days). Additionally, abrasion tests demonstrated resistance exceeding 50,000 rubbing cycles without damage. This research presents a novel and sustainable approach for producing high-performance bio-based artificial leathers.

Thomasset and Benayoun (2024), in a study entitled "Assessing the Durability of Diverse Leather Tanning Techniques for the Manufacturing of Leather Goods through Artificial Aging Processes," compared the durability of leathers tanned using triazine, chrome, and combined synthetic/natural tannins under artificial aging conditions involving heat, humidity, ultraviolet radiation, and microbial exposure. Evaluations based on standard industrial physical–mechanical tests and chemical analyses showed that although aging significantly affected leather properties, finished leathers—especially those with suitable protective layers—experienced minimal degradation and remained suitable for use. The findings underscore the importance of finishing processes in extending leather service life, particularly for triazine-tanned leathers.

He et al. (2023), in a study entitled "Preparation of Modified CO_2-Based Polyurethane for WetType Artificial Leather with Excellent Alkali Resistance," investigated the preparation of wettype artificial leather (WPL) based on polyurethane derived from polypropylene carbonate diol (PPCD) modified with polytetramethylene ether glycol (PTMG). The aim was to enhance alkali resistance, a known weakness of PPCD-based polyurethanes. Extensive analyses including chemical structure, viscosity, mechanical and thermal properties, and microscopic evaluation were performed. After 24 h exposure to a 10 wt% NaOH solution, the modified leathers maintained mechanical strength and exhibited negligible deformation. These results demonstrate that properly modified PPCD can serve as a highly durable material for artificial leather production under harsh alkaline conditions.

Hossain et al. (2021) conducted a study entitled "Quality Assessment of Shoe Leather Based on the Properties of Strength and Comfort, Collected from Different Footwear and Leather Industries in Bangladesh." The objective was to evaluate the quality of upper shoe leathers in terms of physical and chemical properties affecting durability and comfort. Ten

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leather samples from cowhide and goatskin were collected from different Bangladeshi industries and analyzed according to international standards of the International Union of Leather Technologists and Chemists Societies. Tests included tensile strength, elongation, tear resistance, water vapor permeability, flexing and scratch resistance, color fastness, and chemical properties such as pH, fat content, and chromium content. Results showed that only five samples met ISO quality standards, while others were deemed unacceptable due to deficiencies in certain parameters. The study emphasizes the need for improved quality control methods to enhance acceptance and reduce waste in the footwear industry.

Table 1. Research Background (Domestic and International Studies)

Research Conclusions	Type of Test	Type of Leather	Article Title	Researcher(s) (Year)
Domestic Studies				
Improvement of composite mechanical properties and effective recycling of leather waste	Tensile strength, elongation at break	Processed chrometanned leather waste	Investigation of the Effect of Adding Processed Leather Waste on the Mechanical Properties of Polyester Composites	Radmard et al. (1402)
A curing temperature of 190 °C and optimal curing time	Tensile, thermal analysis, colorimetry	PVC artificial leather	Effect of Curing Time and Temperature on the	Zamani and Shakriyeh (1402)
improved mechanical properties; controlled curing was effective without the use of specific additives			Properties of PVC Artificial Leather	
Increased hardness and resistance; dependence on curing system type; leather fibers show potential as reinforcing agents	Vulcanization, hardness, density, abrasion resistance	Natural leather fibers	Effect of Leather Fibers on Vulcanization and Physical– Mechanical Properties of Elastomeric Blends	Shabani et al. (1386)
International Studies				
Best performance achieved with wet-blue leather and an aspect ratio of 6:1; highlights the importance of leather type and particle size selection for durable composites	Thermal, mechanical, morphological, abrasion, tear tests	Leather waste (with different tanning methods)	Upcycling of Leather Waste: Effect of Leather Type and Aspect Ratio on TPU Performance	Nazir et al. (2025)
High strength and toughness; excellent hydrolysis resistance; suitable for sustainable and durable artificial leather	Tensile, toughness, hydrolysis test, abrasion	Bio-based artificial leather	Waterborne Bio-Based Polyurethane with High Abrasion and Hydrolysis Resistance	Zhou et al. (2024)

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Leathers with protective coatings showed higher durability; triazinetanned leather exhibited superior aging resistance	Physical– mechanical, thermal, UV, microbial tests	Triazine-, chrome-, and synthetic/vegetable tanned leathers	Durability of Tanned Leathers under Artificial Aging Conditions	Tomasset and Benayoun (2024)
High resistance in alkaline solutions;	Chemical structure,	Wet artificial leather (WPL)	Modified CO_2Based	He et al. (2023)
PTMG modification improved mechanical performance and chemical stability	mechanical, thermal, alkali resistance		Polyurethane for Alkali-Resistant Wet Artificial Leather	
Only five samples met ISO standards; emphasizes the need for improved quality control in the leather and footwear industries	Tensile, tear, flexing, abrasion, pH, fat content, chromium, water vapor permeability, color fastness	Cow and goat leather (footwear)	Evaluation of Footwear Leather Quality in Bangladesh in Terms of Strength and Comfort	Hossain et al. (2021)

Review of Research Background and Summary

The review of prior studies indicates that incorporating leather waste into various polymer matrices can enhance mechanical properties, durability, and sustainability of composites and artificial leathers. Domestic studies primarily focus on waste reutilization and optimization of thermal processing conditions, whereas international studies emphasize environmental considerations, resistance under harsh conditions, and technological innovations in material formulations. Overall, these studies highlight the importance of recycling, material optimization, and advanced technologies in improving the performance and sustainability of leather products.

3. Materials and Methods

This research is experimental and causal–comparative in nature and investigates the performance characteristics of various leathers, including cowhide, goatskin, ostrich leather, artificial leathers (PU and PVC), and synthetic leather. Samples were prepared according to standard procedures and subjected to specific tests (abrasion resistance, tensile strength, moisture penetration, color change, and chemical resistance). Testing instruments and methodologies complied with international standards (such as ASTM and ISIRI). The independent variable was leather type, and dependent variables were the outcomes of each test. Data were analyzed using descriptive and inferential statistical methods (including t-test and ANOVA), and comparative results were presented to evaluate quality and determine the superior leather type.

The laboratory phase involved sample preparation and conducting standardized tests to evaluate performance characteristics. Leather samples (cowhide, goatskin, ostrich, artificial PU and PVC, and synthetic leather) were cut and prepared according to relevant standards (ASTM, ISIRI, or ISO) with specified dimensions and conditions. Tests were conducted under controlled laboratory conditions using precise equipment, including:

1. Abrasion resistance test: According to ASTM D3884, abrasion equipment was used to measure the number of cycles until complete leather failure.
2. Tensile and tear resistance tests: Based on ASTM D412 or ISO 3376, a tensile testing machine was used to determine the force required for tearing or rupture.
3. Moisture penetration test: According to ASTM D2471 or ISO 22649, the percentage of moisture penetration into leather samples under specified conditions was evaluated.

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4.Color change and chemical resistance tests: Based on ASTM D2813 or ISO 11641, the effects of chemical contact on color change and surface strength under light or heat exposure were assessed.

All experiments were conducted under identical controlled conditions to minimize environmental variability. Data obtained from each test were recorded and used for statistical analysis.

4. Research Findings

Descriptive Statistics

This section compares the apparent properties of the leathers:

Table 2. Descriptive Statistics of Research Variables

Standard Deviation	Mean	Maximum	Minimum	Criterion	Type of Leather
100	2000	2100	1900	Abrasion resistance (Cycles)	Bovine
7	140	145	130	Tensile strength (N)	
1	10	11	9	Moisture permeability (%)	
0.1	1.2	1.3	1.1	Color change (ΔE)	
1.5	95	97	93	Chemical resistance (%)	
150	1800	2000	1600	Abrasion resistance (Cycles)	Caprine
10	120	125	110	Tensile strength (N)	
1.2	12	13	11	Moisture permeability (%)	
0.2	1.5	1.6	1.4	Color change (ΔE)	
1.6	90	92	88	Chemical resistance (%)	
100	2200	2300	2100	Abrasion resistance (Cycles)	Ostrich
8	160	170	150	Tensile strength (N)	
0.8	9	9.5	8.5	Moisture permeability (%)	
0.1	1.0	1.1	0.9	Color change (ΔE)	
1.7	98	100	96	Chemical resistance (%)	
200	1500	1700	1300	Abrasion resistance (Cycles)	PU synthetic
5	90	95	85	Tensile strength (N)	
2	30	32	28	Moisture permeability (%)	
0.3	3.5	3.8	3.2	Color change (ΔE)	
1.7	85	87	83	Chemical resistance (%)	
250	1200	1400	1000	Abrasion resistance (Cycles)	PVC synthetic
6	70	75	65	Tensile strength (N)	
3	40	43	37	Moisture permeability (%)	
0.4	4.0	4.2	3.8	Color change (ΔE)	
2	80	82	78	Chemical resistance (%)	
200	1000	1200	800	Abrasion resistance (Cycles)	Synthetic
7	80	87	73	Tensile strength (N)	
2.5	35	38	32	Moisture permeability (%)	
0.3	2.8	3.1	2.5	Colour change (ΔE)	
2.3	89	92	86	Chemical resistance (%)	

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- Ostrich leather: best performance across all tests due to high strength, minimal color change, and very low moisture penetration.
- Cowhide and goatskin: Acceptable quality and durability, ranking after ostrich leather.
- Artificial leathers (PU and PVC): Despite affordability, high permeability, excessive color change, and low mechanical resistance make them unsuitable for sensitive applications.
- Synthetic leather: Environmentally friendly but exhibits weaker resistance performance.

Inferential Statistics

This section presents complementary tests:

Table 3. Independent t-test Results for Abrasion Resistance

T statistic	p value	Test type	Statistical result
4.25	0.02	Abrasion resistance test	Statistically significant difference between natural and synthetic leather

Table 4. One-Way ANOVA Results for Tensile Strength

F statistic	p value	Test type	Statistical result
15.67	0.001	Tensile strength test	Statistically significant difference among five types of leather

Table 5. Independent t-test Results for Moisture Penetration

T statistic	p value	Test type	Statistical result
5.18	0.005	Moisture permeability test	Statistically significant difference between natural and synthetic leather

Table 6. Independent t-test Results for Colour Change and Chemical Resistance

F statistic	p value	Test type	Statistical result
6.02	0.003	Colour change under chemical exposure test	Statistically significant difference between natural and synthetic leather

Table 7. Summary Table of Results for Each Leather Type Across All Properties

Final Conclusion	Overall Rank	Moisture Permeability (%)	Color Change (ΔE)	Tensile Strength (N)	Abrasion Resistance (Cycles)	Type of Leather
Excellent performance in all tests	2	10	1.2	140	2000	Bovine
Good performance, but slightly inferior to bovine leather	3	12	1.5	120	1800	Caprine
Best performance across all evaluated criteria	1	9	1.0	160	2200	Ostrich
Moderate performance compared to natural leather	4	30	3.5	90	1500	PU synthetic
Poor performance, suitable for limited applications	5	40	4.0	70	1200	PVC synthetic
Average quality and low overall ranking	6	35	2.8	80	1000	Synthetic

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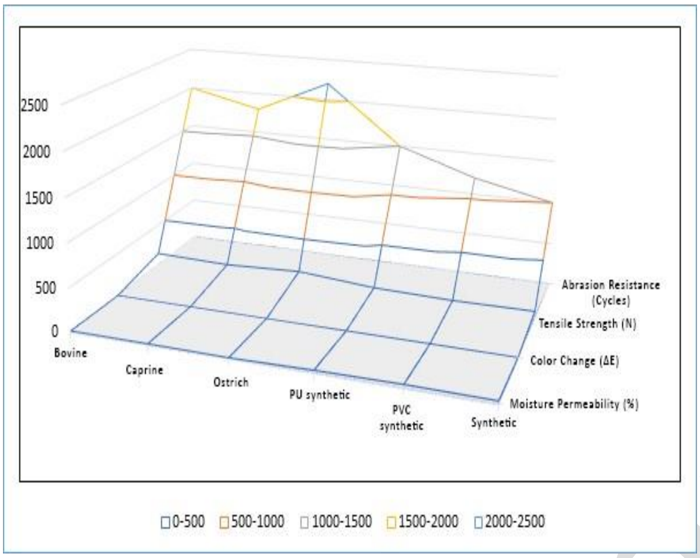

Figure 1. Comparison of leathers across evaluated properties

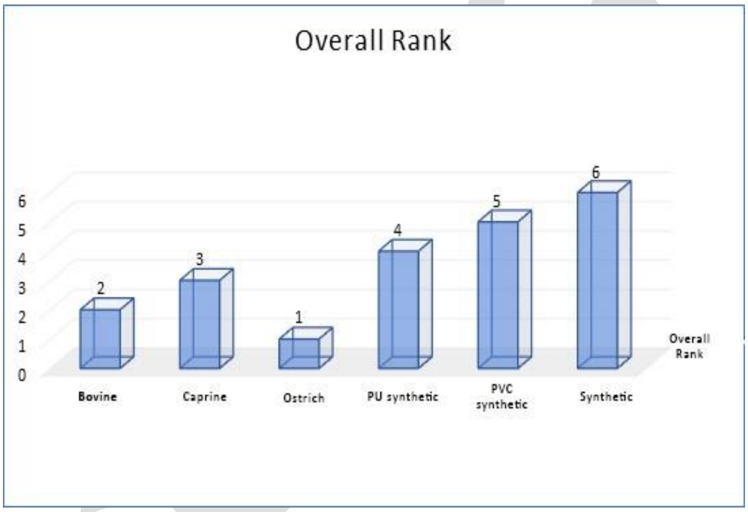

Figure 2. Comparison of overall rankings across evaluated properties

The results indicate substantial differences in abrasion and tensile resistance between natural leathers (cowhide, goatskin, ostrich) and artificial leathers. Ostrich leather was identified as the best leather type in terms of abrasion resistance, tensile strength, and moisture penetration. Artificial PVC leather and synthetic leather exhibited the lowest quality and durability. Statistical test results confirmed significant differences across all evaluated indicators (p-value < 0.05 in all cases).

5. Conclusion

The present study aimed to evaluate and compare the performance characteristics of various leathers, including cowhide, goatskin, ostrich leather, artificial leathers (PU and PVC), and synthetic leather, based on abrasion resistance, tensile strength, moisture penetration, color change, and chemical resistance tests. The results demonstrated that natural leathers particularly ostrich leather exhibited superior quality due to high abrasion resistance (mean of 2200 cycles), high tensile strength (mean of 160 N), low moisture permeability (9%), and minimal color change ($\Delta E=1.0$). Cowhide also showed favorable performance across all tests (e.g., abrasion resistance of 2000 cycles and color change $\Delta E=1.2$), ranking second after ostrich leather and being identified as a durable and reliable option.

In contrast, artificial leathers especially PVC performed poorly in abrasion resistance (1200 cycles), tensile strength (70 N), and moisture penetration (40%), indicating limitations

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for use in harsh or long-term conditions. Synthetic leather also showed weaker performance in certain tests, such as abrasion resistance (1000 cycles) and moisture permeability (35%); however, its main advantage lies in reduced environmental impact. Due to the use of eco-friendly materials and avoidance of harmful chemicals during production, synthetic leather may be a suitable option for environmentally conscious consumers, representing a significant strength of this leather type.

Results from color change and chemical resistance tests indicated that natural leathers are more resistant to chemical agents and environmental factors, with ostrich leather exhibiting the least color change upon chemical exposure. In contrast, artificial leathers showed considerably higher color change ($\Delta E = 4.0$ for PVC).

Overall, ostrich leather is identified as the optimal option in terms of durability, strength, and overall quality, followed by cowhide as a suitable choice for general and industrial applications. Artificial and synthetic leathers are recommended for applications where resistance and durability are less critical. This study demonstrates the overall superiority of natural leathers particularly ostrich and cowhide over artificial and synthetic leathers and emphasizes the importance of considering structural and functional properties when selecting appropriate leather types.

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