



MATERIAL QUALITY ANALYSIS OF GARMENT LEATHERS FOR SUSTAINABLE LEATHER AND FOOTWEAR DESIGN

Scientific paper
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ABSTRACT: Leather is a widely used material in the garment and footwear industry due to its durability, flexibility, aesthetic appeal, and comfort. The performance of leather products largely depends on the intrinsic properties of the raw material and the finishing techniques applied. This study focuses on the quality characterization of different types of garment leathers with reference to their suitability for sustainable leather and footwear design. Various leather types, including cowhide, sheepskin, lambskin, and goatskin, along with different finishing techniques such as aniline, semi-aniline, pigmented, nubuck, and suede, were evaluated. Standard physical performance tests, including colour fastness, tear strength, tensile strength, thickness, and water repellency, were conducted to assess their quality characteristics. The results indicate that pigmented leather exhibits superior colour fastness and water repellency, making it suitable for applications requiring high durability and environmental resistance. In contrast, aniline leather shows lower resistance to environmental factors but offers better aesthetic appeal. Among the leather types studied, cow nubuck leather demonstrates the highest thickness, tensile strength, and tear resistance, indicating superior mechanical performance, while lamb nappa leather provides enhanced softness and comfort for premium applications. The study highlights that finishing processes significantly influence surface-related properties, whereas intrinsic fibre structure governs mechanical performance. These findings provide valuable insights for selecting appropriate leather materials for specific garment and footwear applications, contributing to improved product performance and sustainable design practices.

Keywords: Leather quality characterisation, Garment and footwear applications, Leather finishing technique, Mechanical properties of leather, Sustainable leather design.

ANALIZA KVALITETA MATERIJALA OD KOŽE ZA ODRŽIVI DIZAJN KOŽE I OBUĆE



APSTRAKT: Koža je široko korišćeni materijal u industriji odeće i obuće zbog svoje izdržljivosti, fleksibilnosti, estetske privlačnosti i udobnosti. Performanse kožnih proizvoda u velikoj meri zavise od suštinskih svojstava sirovine i primenjenih tehnika završne obrade. Ova studija se fokusira na karakterizaciju kvaliteta različitih vrsta kože za odeću u odnosu na njihovu pogodnost za održivi dizajn kože i obuće. Procenjene su različite vrste kože, uključujući kravlju, ovčiju, jagnjeću i kozju kožu, zajedno sa različitim tehnikama završne obrade kao što su anilin, poluanilin, pigmentirana, nubuk i velur. Standardni testovi fizičkih performansi, uključujući postojanost boje, čvrstoću na kidanje, zateznu čvrstoću, debljinu i vodoodbojnost, sprovedeni su kako bi se procenili njihovi kvalitetni karakteristike. Rezultati pokazuju da pigmentirana koža pokazuje superiornu postojanost boje i vodoodbojnost, što je čini pogodnom za primene koje zahtevaju visoku izdržljivost i otpornost na uticaje okoline. Nasuprot tome, anilinska koža pokazuje manju otpornost na faktore okoline, ali nudi bolju estetsku privlačnost. Među proučavanim tipovima kože, goveđa nubuk koža pokazuje najveću debljinu, zateznu čvrstoću i otpornost na kidanje, što ukazuje na superiorne mehaničke performanse, dok jagnjeća napa koža pruža poboljšanu mekoću i udobnost za premium primene. Studija ističe da procesi završne obrade značajno utiču na površinska svojstva, dok unutrašnja struktura vlakana upravlja mehaničkim performansama. Ovi nalazi pružaju vredne uvide za izbor odgovarajućih kožnih materijala za specifične primene u odeći i obući, doprinoseći poboljšanim performansama proizvoda i održivim praksama dizajna.

Ključne reči: Karakterizacija kvaliteta kože, Primena u odeći i obući, Tehnika završne obrade kože, Mehanička svojstva kože, Održivi dizajn kože.

1. INTRODUCTION

Leather is a versatile and durable material widely used in the garment industry due to its strength, flexibility, and softness. It is a biological material derived from animal hides and skins and converted into a stable product through chemical treatment known as tanning. Raw materials include hides from large animals such as cows and horses and skins from smaller animals such as sheep, goats, pigs, and calves. In the leather industry, the term *hides* refers to skins from larger animals, while *skins* refer to those from smaller animals. Animal hides consist of three structural layers: epidermis, corium, and flesh layer. Among these, the corium layer is most important for leather production because it contains collagen fibres that provide strength and durability to the material [1].

Leather manufacturing involves several important steps, including cleaning, tanning, retanning, milling, and finishing. During cleaning, impurities such as hair, dirt, and fats are removed from raw hides. Tanning stabilizes the collagen fibres using chemical agents, making the material resistant to decomposition, moisture, and microorganisms. Retanning improves leather quality through dyeing and fat liquoring, while milling enhances softness. Finally, finishing processes such as dyeing, coating, waxing, embossing, and oiling improve the appearance and performance of leather [2].

Different types of leather are produced depending on the raw material source, manufacturing process, and finishing treatments. Common leathers used in garment manufacturing include cowhide, sheepskin, lambskin, and goatskin, each possessing properties such as strength, softness, breathability, and flexibility. Finishing methods such as aniline, semi-aniline, pigmented, suede, and nubuck finishes enhance visual appearance and influence properties such as colour fastness, abrasion resistance, softness, and water resistance, which are important for garment applications [3].

Maintaining leather quality is essential in the garment industry to ensure durability and functionality. Quality characterization is performed through physical and chemical tests such as tensile strength, tear strength, thickness measurement, colour fastness, and water repellency tests to evaluate the performance and suitability of leather materials [4]. Therefore, this study focuses on the quality characterization of different types of leather used in the garment industry by evaluating their physical properties to obtain a comparative understanding of their performance characteristics.

2. MATERIALS AND METHODS

2.1 Leather Manufacturing Process

- **Cleaning:** Animal hides and skins are preserved using salt or refrigeration during transportation to prevent microbial degradation. During cleaning, impurities such as dirt, hair, residual salts, and excess fats are removed through degreasing. This stage, also known as wet processing, prepares the hides for further treatment and the cleaned hides are graded into categories such as full grain leather, top grain leather, nubuck leather, and suede leather.
- **Tanning:** Tanning stabilizes the collagen fibres present in animal hides, improving resistance to microbial attack, environmental degradation, and chemical reactions. Common tanning methods include chrome tanning, vegetable tanning, and chrome-free tanning. Chrome-tanned leather is known as wet-blue leather, while leather processed without chrome is referred to as wet-white leather (Walton).
- **Retanning:** Retanning determines the final characteristics of leather. Dyeing is carried out to impart colour, and fat liquoring improves softness, flexibility, and fullness. Leather obtained after this stage is called crust leather, and the process helps modify leather properties according to applications such as garments, footwear, and upholstery [2].
- **Milling:** Milling is a mechanical treatment used to soften leather and enhance the natural grain structure. Leather is placed in rotating drums where the tumbling action improves softness and produces a natural grainy texture.
- **Finishing:** Finishing is the final stage of leather manufacturing. Processes such as dyeing, coating, waxing, oiling, and embossing are applied to improve the aesthetic appearance, durability, colour uniformity, and resistance to environmental factors of leather products [5].



2.2 Types of Leather

Different types of leather are used in the garment industry depending on the animal source and the properties required for specific applications. Each type possesses unique characteristics such as softness, durability, flexibility, and texture [6].

- **Cowhide Leather:** Cowhide leather is strong, durable, and resistant to wear. Due to its thickness and rugged nature, it is widely used for jackets, belts, footwear, and bags. It is commonly preferred for garments that require higher durability, such as biker jackets.
- **Sheepskin Leather:** Sheepskin leather is lightweight, soft, and flexible. It provides excellent comfort and easily adapts to body shape over time. Because of its smooth texture and softness, it is widely used in garment manufacturing.
- **Lambskin Leather:** Lambskin leather is considered a luxury leather due to its extremely smooth surface and soft texture. It is commonly used in high-end garments, coats, and fashion accessories because of its superior softness and aesthetic appearance.
- **Goatskin Leather:** Goatskin leather contains natural lanolin, which gives it a smooth and soft texture. It is lighter than cowhide leather but offers good durability and flexibility. Its distinctive grain pattern makes it suitable for garments, bags, and footwear.

2.3 Types of Leather Finishes

Leather finishing processes significantly influence the appearance and performance characteristics of leather products. Common finishes include aniline, semi-aniline, pigmented leather, suede, and nubuck finishes [3].

- **Aniline Finish:** Aniline leather is produced using water-soluble dyes without heavy surface coatings. This finish preserves the natural grain structure and provides a soft, luxurious appearance, but it is more susceptible to staining and fading.
- **Semi-Aniline Finish:** Semi-aniline leather has a thin protective coating that improves resistance to stains and sunlight while maintaining the natural grain appearance.
- **Pigmented Leather:** Pigmented leather contains a thicker resin-based coating that provides better abrasion resistance and colour uniformity, although it reduces breathability.
- **Suede:** Suede leather is produced by buffing the inner surface of the hide to create a soft and velvety texture. It is widely used in gloves, footwear, and fashion accessories.
- **Nubuck:** Nubuck leather is produced by buffing the outer grain surface to create a fine velvety texture. Compared to suede, nubuck is stronger and more durable.

2.4 Testing of Leather

Quality testing of leather is essential to ensure that leather products meet industry standards and customer expectations. Both chemical and physical tests are conducted to evaluate the performance of leather materials.

- **Chemical Testing:** Certain chemicals used during leather processing may produce harmful compounds such as aromatic amines. According to EU REACH regulations,



the permissible limit for these chemicals in leather products is 30 mg/kg (Eui Kyung Roh).

- **pH Testing:** The pH value of leather indicates the acidity or alkalinity of the material and influences the durability of the finished product. Chromium-tanned leather generally has a pH range between 3.2 and 5.5 [7]
- **Chromium VI Testing:** Chromium VI is a harmful compound that may form during chrome tanning. International regulations restrict its concentration to less than 3 mg/kg in leather products to prevent allergic reactions.

3. RESULT AND DISCUSSION

3.1 Testing of Leather

Azo colourants used in leather dyeing may generate toxic aromatic amines. Since these compounds are carcinogenic, strict regulations have been established by the EU and other countries to ensure that leather products are free from such harmful substances.

3.2 Legal Limit for Chemical Properties of Leather

Restricted chemicals in leather products are specified in Appendix 10 of the EU REACH regulations. According to Annex XVII, the permissible limit for each aromatic amine in leather is 30 mg/kg. Leather products meeting this requirement can obtain an Eco-label. Chinese regulations set a stricter limit of 20 mg/kg for toxic substances.

3.3 Testing Methods

Restricted chemicals in leather are identified through extraction and chemical reaction methods using the following standards:

- Determination of aromatic amines extracted from azo colourants (EN ISO 17234-1:2010)
- Determination of 4-aminoazobenzene (EN ISO 17234-2:2011)

3.4 Testing Leather for pH Value

The pH value indicates the acidity or alkalinity of leather and influences the durability of the finished product. It also reflects the effectiveness of tanning and dyeing processes. pH can be measured either in solution or directly on the leather sample.

3.4.1 Testing Methods

pH testing can be performed using damp indicator paper for a quick estimate or by cutting the leather sample and measuring according to EN ISO 4045:2008 for accurate results. The pH scale ranges from 0–14:

- pH 1–7: Acidic
- pH 7: Neutral
- pH 8–14: Alkaline
- 3.4.2 Meaning of Test Results



Chromium-tanned leather normally has a pH range of 3.2–5.5. Excessive acidity may indicate poor tanning, leading to premature deterioration, whereas high alkalinity may cause improper dye fixation and colour fading.

3.5 Testing Leather for Chromium VI Compounds

Chromium (VI) may form during chrome tanning and can cause severe allergic reactions. Therefore, leather products sold in the EU must contain less than 3 mg/kg of Chromium VI.

3.5.1 Test Methods

The determination of Chromium (VI) content in leather is performed according to EN ISO 17075 using chemical extraction methods, followed by colorimetric or chromatographic analysis.

3.5.2 Meaning of Test Results

The Chromium (VI) content must not exceed 3 mg/kg (0.0003%) of the dry weight of leather when the pH is between 7.5 and 8.

3.6 Physical Tests for Leather

Physical tests simulate actual usage conditions to evaluate the durability and performance of leather products.

- Wetting Resistance (Spray Test): Evaluates the water repellency of the leather surface.
- Adhesive Properties of Finishing: Determines the adhesion of finishing layers on leather.
- Tear Load Test: Measures the force required to tear leather through two holes and assesses stitch tear resistance.
- Tensile Strength Test: Determines the load required to rupture leather using a 12.7 mm diameter specimen.
- Colour Fastness Test: Evaluates the resistance of coloured leather to washing and staining of adjacent fabrics.
- Relative Stiffness Test: Measures the stiffness of leather using a torsional apparatus.

3.7 Evaluation

Testing of leather products helps determine their quality and authenticity. Quality characterization ensures that leather meets the required standards for its intended application and confirms that the product satisfies consumer expectations.

3.8 Leathers used in Timberland Products

Timberland shoes and boots are mostly made of authentic leather. Timberland is a firm believer in natural leather and full grain because they feel that leather goods can improve



with age and last a long time. Pig, horse, horse, and cow hides were also used. They use a number of surface appearances, such as the ones mentioned below.

- Full grain (as it ages it is the best with patina)
- Nubuck is a type of leather that is used (a velvety premium suede look)
- Suede is a kind of suede that is (the bottom layer of the hide which is not as strong)
- Smooth finish with a smooth surface that contributes to the elegance and consistency of the surface.
- Milled leather is top grain leather that has been turned in a milling machine.

Quality Characterization of Leather in Timberland Products is shown in Table 1. Comparative Analysis of Quality Characterization of Leather in Timberland Products is indicated in Figure 1.

Table 1: Quality Characterization of Leather in Timberland Products

TESTS	PIGMENTED LEATHER	SEMI-ANILINE LEATHER	ANILINE LEATHER	NUBUCK AND SUEDE LEATHER
Colour fastness to light	4	4	2/3	4
Colour fastness to rubbing	Dry 3, Wet 2/3	Dry 3, Wet 2/3	Dry 3, Wet 2/3	Dry 3, Wet 2/3
Colour fastness to water spotting	3 (no residual halo)	3 (no residual halo)	3 (no residual halo)	3 (no residual halo)
Colour fastness to water	3	3	3	3
Colour fastness to dry cleaning	3 (no finish loss, no reoiling)	3 (no finish loss, no reoiling)	3 (no finish loss, no reoiling)	3 (no finish loss, no reoiling)
Tear strength	20 N	20 N	20 N	20 N
Water repellency	100	90	80	80

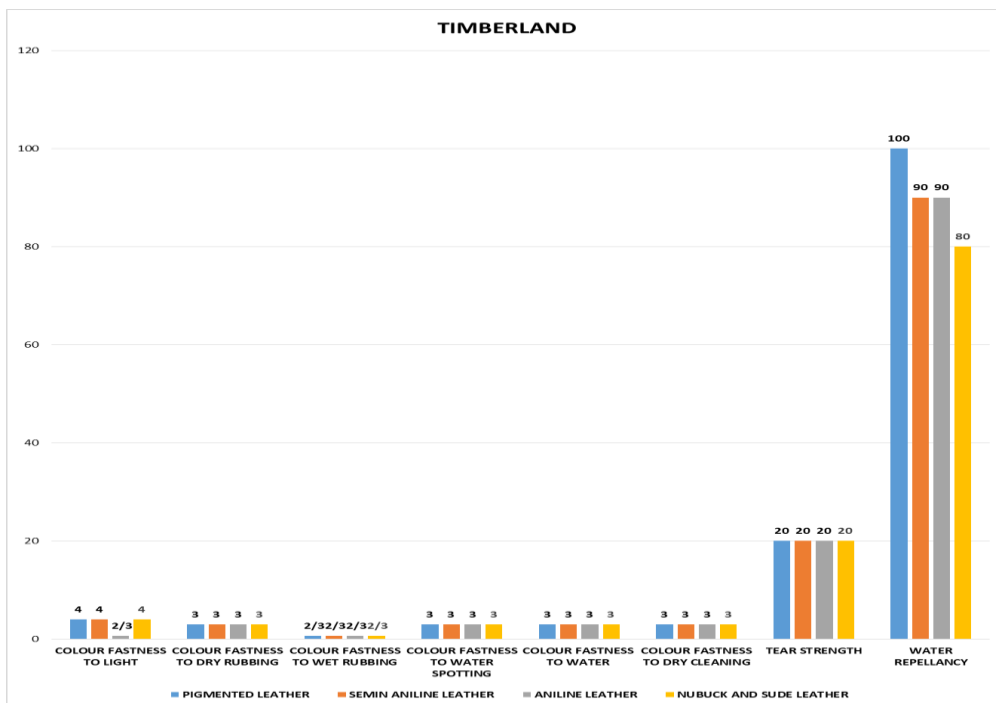


Figure 1: Comparative Analysis of Quality Characterization of Leather in Timberland Products

Table 1 presents the quality characterization of different leather finishes used in Timberland products, including pigmented, semi-aniline, aniline, and nubuck/suede leathers. It is observed that pigmented leather exhibits superior colour fastness to light (rating 4) and the highest water repellency (100%), indicating its enhanced resistance to environmental exposure. Semi-aniline leather also shows comparable colour fastness but slightly lower water repellency (90%). In contrast, aniline leather demonstrates relatively lower colour fastness to light (2/3), which can be attributed to the absence of protective surface coatings. All leather types exhibit similar performance in terms of tear strength (20 N) and colour fastness to rubbing, indicating that finishing primarily influences surface properties rather than mechanical strength.

Figure 1 further illustrates these trends, clearly showing that pigmented leather outperforms other finishes in durability-related properties, while nubuck and suede maintain moderate performance with aesthetic advantages.

3.9. Leathers used in Tommy Hilfiger Products

Leathers products from Tommy Hilfiger are tested for its quality characteristics are Lamb nappa leather, Goat suede leather and Cow nubuck leather. Quality Characterization of Leather in Tommy Hilfiger Products is tabulated in Table 2. Comparative Analysis of Quality Characterization of Leather in Tommy Products is exhibited in Figure 2. Different types of leather products are given in Figure 3 (Cow Nubuck), Figure 4 (Goat Suede) and Figure 5 (.Lamb Nappa).

Table 2: Quality Characterization of Leather in Tommy Hilfiger Products

LEATHER & TESTS	THICKNESS	TONGUE TEAR STRENGTH ASTM D 4704	TENSILE STRENGTH ASTM D 2209
Lamb Nappa Leather	1.0 mm	5 to 6 lbf	20 to 30 lbf
Goat Suede Leather	0.9 mm	4 to 5 lbf	40 to 50 lbf
Goat Suede Leather	1.1 mm	6 to 7 lbf	60 to 70 lbf
Lamb Nappa Leather	0.7 mm	3 to 4 lbf	10 to 20 lbf
Cow Nubuck Leather	1.3 mm	10 to 15 lbf	70 to 90 lbf

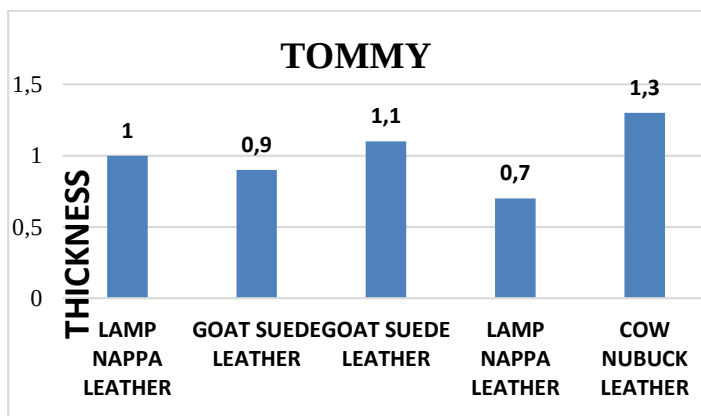


Figure 2: Comparative Analysis of Quality Characterization of Leather in Tommy Products



Figure 3: Cow Nubuck



Figure 4: Goat Suede



Figure 5: Lamb Nappa

Table 2 summarizes the physical and mechanical properties of different leather types used in Tommy Hilfiger products. Among the tested samples, cow nubuck leather exhibits the highest thickness (1.3 mm), tongue tear strength (10–15 lbf), and tensile strength (70–90 lbf), indicating superior structural integrity and durability. Goat suede leather shows moderate mechanical properties, with tensile strength ranging from 40 to 70 lbf depending on thickness, while lamb nappa leather demonstrates lower strength values (10–30 lbf) but offers better softness and flexibility, making it suitable for premium garment applications. Figure 2 provides a comparative visualization of these results, highlighting that mechanical performance increases with thickness and fibre compactness, with cow nubuck leather showing the best overall performance among the tested materials. Figures 3, 4, and 5 illustrate the surface characteristics of cow nubuck, goat suede, and lamb nappa leathers, respectively. Figure 3 (Cow Nubuck): Shows a fine, velvety surface with a dense fibre structure, which contributes to its high tensile and tear strength. Figure 4 (Goat Suede): Exhibits a softer and more porous structure due to buffing of the inner layer, resulting in moderate strength and enhanced flexibility. Figure 5 (Lamb Nappa): Displays a smooth and soft grain surface, characteristic of high-end garment leather, but with comparatively lower mechanical strength. These visual observations correlate well with the mechanical test results, confirming that surface structure and fibre compactness significantly influence the performance properties of leather materials.

The results indicate that finishing type strongly affects surface-related properties (colour fastness, water repellency), whereas intrinsic material structure governs mechanical properties (tensile and tear strength). Pigmented leather and cow nubuck leather emerge as the most suitable materials for applications requiring high durability, while aniline and lamb nappa leathers are more appropriate for aesthetic and comfort-oriented applications.

4. CONCLUSION

The quality is one of the most important characteristics that satisfy the customer's expectations. Here we characterized the quality of the leather from Timberland and Tommy Hilfiger. Different kinds of leather from Timberland such as pigmented leather, aniline



leather, semi-aniline leather, nubuck and suede leather were characterised. The tests done for the quality characterization of these leathers were colour fastness, tear strength and water repellency. The pigmented leather has comparatively good water repellency and colour fastness than other leathers. Leathers products of Tommy Hilfiger were also characterized for its quality purpose and they are lamb nappa leather, goat suede leather and cow nubuck leather. The tests done for the quality characterization of these leathers were thickness, tongue tear strength ASTM D 4704 and tensile strength ASTM D 2209. The cow nubuck leather has comparatively good quality characteristics like thickness, tongue tear strength and tensile strength than other leathers. Hence, Timberland's pigmented leather and Tommy Hilfiger's cow nubuck leather has good quality parameter that satisfies the customer's expectations.

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