COMPARATIVE PHYSICOCHEMICAL ANALYSIS OF INDIGENOUS TRADITIONAL TANNED COWHIDE AND MODERN VEGETABLE-TANNED LEATHER IN THE AMHARA REGION, ETHIOPIA

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ABSTRACT. Despite modern methods being the primary way of producing leather (making up 80-90% of production), there are concerns about the environmental impact of using harmful chemicals like chrome. This study aims to investigate a potential alternative: the indigenous tanning method used in the Amhara region of Ethiopia. The study compares this indigenous method to modern vegetable tanning, assessing the physical and chemical properties of the leather produced, particularly in terms of environmental impact and potential advantages. The goal is to determine whether the eco-friendly nature of the indigenous method gives it a competitive advantage, even if there are differences in the properties of the leather produced. Both unhaired and hair-on indigenous tanned leathers were analyzed and compared with modern vegetable-tanned leather in terms of thickness, tensile strength, tear strength, water absorption, shrinkage temperature, pH, and Fourier Transform Infrared Spectroscopy (FTIR). The study revealed significant differences in physical and chemical properties between unhaired indigenous tanned cowhide leather and hair-on indigenous tanned leather, with modern vegetable-tanned leather being the superior option. Unhaired leather measures 1.32mm, while hair-on leather has a thickness of 1.58mm, both exceeding the recommended minimum value of >0.5mm. The tensile strength of unhaired indigenous cowhide hide leather is 9.62 N/mm², below the recommended value of modern vegetable-tanned leather (>12 N/mm²), while hair-on leather has a tensile strength of 13.41 N/mm². Unhaired indigenous cowhide leather has a higher elongation of 32.13% compared to that of hair-on leather, of 12.47%, neither meeting the recommended (>40%) elongation for vegetable-tanned leather. Unhaired and hair-on indigenous cowhide leathers have a tear strength of 80.33 N and 93.67 N, respectively, both meeting the minimum recommended value of modern vegetable-tanned leather (>20 N). Water absorption of unhaired and hair-on indigenous cowhide leathers is 207.47% and 235.50%, respectively, but do not fulfill the minimum recommended value of modern vegetable-tanned leather after 2 hours (<35%). Traditional cowhide leather, with unhaired and hair-on options, has a shrinkage temperature of 54°C and 50.33°C, respectively. The pH of unhaired indigenous cowhide leather is 6.1, while hair-on indigenous cowhide leather is 6.6. In FTIR tests, unhaired indigenous cowhide leathers have fewer single and double bonds, while hair-on indigenous cowhide leathers have more single, double, and triple bonds and fingerprints. The indigenous tanning method is a more environmentally friendly alternative to the modern vegetable tanning method. The study found that the indigenous tanning method produced leather that was comparable in quality to the modern vegetable tanning method. This suggests that the indigenous tanning method could be a viable alternative to the modern vegetable tanning method, especially in areas where environmental concerns are a priority.

KEYWORDS: indigenous tanning method, cow hides, physico-chemical properties, modern vegetable tanning

ANALIZĂ FIZICO-CHIMICĂ COMPARATIVĂ ÎNTRE PIELEA BOVINĂ TĂBĂCITĂ TRADIȚIONAL ȘI PIELEA TĂBĂCITĂ VEGETAL UTILIZÂND METODE MODERNE, ÎN REGIUNEA AMHARA, ETIOPIA

REZUMAT. Deși metodele moderne reprezintă principala modalitate de fabricare a pielii (reprezentând 80-90% din producție), există îngrijorări cu privire la impactul asupra mediului al utilizării substanțelor chimice nocive, precum cromul. Prezentul studiu își propune să investigheze o potențială alternativă: metoda tradițională de tăbăcire utilizată în regiunea Amhara din Etiopia. Studiul compară această metodă cu tăbăcirea vegetală modernă, evaluând proprietățile fizice și chimice ale pieilor obținute, în special din perspectiva impactului asupra mediului și a avantajelor potențiale. Scopul este de a stabili dacă caracterul ecologic al metodei tradiționale îi conferă un avantaj competitiv, chiar dacă există diferențe în ceea ce privește proprietățile pieilor obținute. Atât pieile tăbăcite tradițional fără păr, cât și cele cu păr, precum și pielea tăbăcită vegetal utilizând metode moderne s-au analizat comparativ în ceea ce privește grosimea, rezistența la rupere, rezistența la sfâșiere, absorbția apei, temperatura de contracție, pH-ul și spectroscopia în infraroșu cu transformată Fourier (FTIR). Studiul a evidențiat diferențe semnificative în ceea ce privește proprietățile fizice și chimice între pielea bovină tăbăcită tradițional, fără păr, și pielea tăbăcită tradițional, cu păr, pielea tăbăcită vegetal utilizând metode moderne fiind opțiunea superioară. Pielea fără păr are o grosime de 1,32 mm, în timp ce pielea cu păr are o grosime de 1,58 mm, ambele depășind valoarea minimă recomandată de >0,5 mm. Rezistența la rupere a pielii bovine fără păr tăbăcite tradițional este de 9,62 N/mm², sub valoarea recomandată pentru pielea tăbăcită vegetal cu tehnici moderne (>12 N/mm²), în timp ce pielea cu păr are o rezistență la rupere de 13,41 N/mm². Pielea bovină fără păr tăbăcită tradițional prezintă o alungire mai mare, de 32,13%, comparativ cu cea a pielii cu păr, de 12,47%, care nu îndeplinește cerința recomandată (>40%) pentru pielea tăbăcită vegetal. Atât pielea bovină fără păr tăbăcită tradițional, cât și cea cu păr au o rezistență la rupere de 80,33 N și, respectiv, 93,67 N, îndeplinind valoarea minimă recomandată pentru pielea tăbăcită vegetal cu tehnici moderne (>20 N). Absorbția de apă a pieilor bovine fără păr și cu păr tăbăcite tradițional este de 207,47% și, respectiv, 235,50%, dar nu îndeplinește valoarea minimă recomandată pentru pielea modernă tăbăcită vegetal după 2 ore (<35%). Pielea bovină tăbăcită tradițional, disponibilă atât în varianta fără păr, cât și cu păr, are o temperatură de contracție de 54 °C, respectiv 50,33 °C. pH-ul pieilor bovine fără păr este de 6,1, în timp ce al pieilor bovine cu păr este de 6,6. În urma testelor FTIR, s-a constatat că pieile bovine fără păr tăbăcite tradițional prezintă mai puține legături simple și duble, în timp ce pieile bovine cu păr tăbăcite tradițional prezintă mai multe legături simple, duble și triple, precum și amprente. Metoda tradițională de tăbăcire reprezintă

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o alternativă mai ecologică față de metoda modernă de tăbăcire vegetală. În urma studiului, s-a constatat că metoda tradițională de tăbăcire a generat o piele comparabilă din punct de vedere al calității cu metoda modernă de tăbăcire vegetală. Acest lucru sugerează că metoda indigenă de tăbăcire ar putea constitui o alternativă viabilă la metoda modernă de tăbăcire vegetală, în special în zonele în care preocupările de mediu reprezintă o prioritate.
CUVINTE CHEIE: metodă indigenă de tăbăcire, piei bovine, proprietăți fizico-chimice, tăbăcire vegetală modernă

ANALYSE PHYSICO-CHIMIQUE COMPARATIVE DU CUIR BOVIN TANNÉ DE MANIÈRE TRADITIONNELLE ET DU CUIR TANNÉ VÉGÉTAL SELON DES MÉTHODES MODERNES DANS LA RÉGION D'AMHARA, EN ÉTHIOPIE

RÉSUMÉ. Bien que les méthodes modernes constituent le moyen principal de production du cuir (représentant 80 à 90 % de la production), l'utilisation de produits chimiques nocifs tels que le chrome suscite des inquiétudes quant à son impact environnemental. Cette étude vise à examiner une alternative potentielle : la méthode de tannage traditionnelle utilisée dans la région d'Amhara, en Éthiopie. L'étude compare cette méthode traditionnelle au tannage végétal moderne, en évaluant les propriétés physiques et chimiques du cuir obtenu, notamment en termes d'impact environnemental et d'avantages potentiels. L'objectif est de déterminer si le caractère écologique de la méthode traditionnelle lui confère un avantage concurrentiel, même s'il existe des différences dans les propriétés du cuir obtenu. Des cuirs tannés selon la méthode traditionnelle, tant sans poils qu'avec poils, ont été analysés et comparés au cuir au tannage végétal moderne en termes d'épaisseur, de résistance à la traction, de résistance à la déchirure, d'absorption d'eau, de température de rétrécissement, de pH et de spectroscopie infrarouge à transformée de Fourier (FTIR). L'étude a révélé des différences significatives dans les propriétés physiques et chimiques entre le cuir bovin au tannage traditionnel sans poils et le cuir au tannage traditionnel avec poils, le cuir tanné végétal selon des méthodes modernes s'avérant être la meilleure option. Le cuir sans poils mesure 1,32 mm, tandis que le cuir avec poils présente une épaisseur de 1,58 mm ; ces deux valeurs dépassent la valeur minimale recommandée de >0,5 mm. La résistance à la traction du cuir bovin indigène sans poils est de 9,62 N/mm², ce qui est inférieur à la valeur recommandée pour le cuir au tannage végétal moderne (> 12 N/mm²), tandis que le cuir avec poils présente une résistance à la traction de 13,41 N/mm². Le cuir bovin indigène sans poils présente un allongement plus élevé (32,13 %) que celui du cuir avec poils (12,47 %), ce qui ne répond pas à la valeur recommandée (> 40 %) d'allongement pour le cuir tanné végétal. Les cuirs bovins indigènes, tant sans poils qu'avec poils, présentent une résistance à la déchirure de 80,33 N et 93,67 N respectivement, ce qui satisfait à la valeur minimale recommandée pour le cuir tanné végétal moderne (> 20 N). L'absorption d'eau des cuirs bovins indigènes sans poils et avec poils est respectivement de 207,47 % et 235,50 %, mais ne répond pas à la valeur minimale recommandée pour les cuirs au tannage végétal moderne après 2 heures (<35 %). Le cuir bovin au tannage traditionnel, disponible en version « sans poils » et « avec poils », présente respectivement une température de rétrécissement de 54 °C et 50,33 °C. Le pH du cuir bovin indigène sans poils est de 6,1, tandis que celui du cuir bovin indigène avec poils est de 6,6. Lors des tests FTIR, les cuirs bovins indigènes sans poils présentent moins de liaisons simples et doubles, tandis que les cuirs bovins indigènes avec poils présentent davantage de liaisons simples, doubles et triples, ainsi que des empreintes. La méthode de tannage indigène constitue une alternative plus respectueuse de l'environnement que la méthode moderne de tannage végétal. L'étude a révélé que la méthode de tannage traditionnelle permettait d'obtenir un cuir dont la qualité était comparable à celle obtenue par la méthode moderne de tannage végétal. Cela suggère que la méthode de tannage traditionnelle pourrait constituer une alternative viable à la méthode moderne de tannage végétal, en particulier dans les régions où les préoccupations environnementales sont une priorité.
MOTS-CLÉS : méthode de tannage traditionnelle, cuir bovin, propriétés physico-chimiques, tannage végétal moderne

INTRODUCTION

Ethiopia possesses one of the largest livestock populations in Africa, serving as a major source of livelihood for rural communities and an important supply base for the leather industry. The country produces an estimated 2.4 million hides, 10 million sheepskins, and 7.4 million goatskins annually [1]. Ethiopian sheep predominantly produce hair-type skins that are highly valued for their compact fiber structure and superior tensile strength [2]. The leather sector contributes significantly to the national economy through employment generation, value addition, and export earnings.

Tanning is one of the oldest human technologies and involves the chemical stabilization of animal hides and skins to produce leather that is resistant to microbial degradation, moisture, and mechanical wear. Through tanning, collagen fibers are transformed into a durable, flexible, and functional material suitable for various applications [3]. While modern tanning industries employ advanced machinery, specialized tanning agents, and controlled processing conditions to achieve consistent leather quality, traditional tanning systems continue to play an important role in many developing countries, particularly in rural communities [4].

Ethiopia has a substantial traditional tanning sector, with more than 6,722 households engaged in indigenous leather processing across the Amhara, Tigray, and Oromia regions. Of these, approximately 5,292 traditional tanners are located in the Amhara region alone, processing more than 700,000 hides annually due to the accessibility of raw materials and local market demand [5]. The Amhara region is particularly recognized for its rich cultural heritage and long-standing indigenous tanning traditions, making it an important area for investigating the characteristics and performance of traditionally processed leather [6].

Traditional tanning practices in the Amhara region rely primarily on locally available botanical resources rather than synthetic tanning chemicals. Indigenous tanners commonly prepare tanning liquors from tannin-rich plant materials obtained from the bark, leaves, roots, fruits, and seed pods of native vegetation, including species of *Acacia*, *Cordia africana*, *Vernonia amygdalina*, and other locally available plants. These materials contain condensed and hydrolysable tannins, which are polyphenolic compounds capable of forming stable cross-links with collagen fibers in animal hides [5]. In addition, animal fats and other organic materials are often used during hide preservation, lubrication, and softening processes. Because these tanning agents are naturally derived and biodegradable, indigenous tanning systems generally generate fewer hazardous chemical residues than conventional chrome tanning processes, which are associated with chromium-containing effluents and environmental concerns [7].

Despite their environmental advantages, traditional leather production systems in the Amhara region face several challenges. The processing activities are often carried out under cottage-industry conditions and may generate unpleasant odors, solid wastes, and gaseous emissions due to limited waste-management practices [8]. Furthermore, traditionally tanned cowhide leather is frequently characterized by non-uniform thickness, heavy weight, limited color variation, lower water resistance, variable surface appearance, and labor-intensive production methods [1]. Additional constraints include low technology adoption, inconsistent raw material quality, limited access to skilled labor, inadequate financial resources, and weak market linkages [9]. According to [10], traditional hide and skin tanning is commonly practiced as a supplementary livelihood activity rather than as a specialized occupation.

Although indigenous tanning remains culturally and economically important in the Amhara region, limited scientific information is available regarding the physicochemical properties of the resulting leather and how these properties compare with those of modern vegetable-tanned leather. Therefore, this study aimed to evaluate and compare the physicochemical characteristics of indigenous traditional tanned cowhide leather and modern vegetable-tanned leather. The investigation focused on thickness, tensile strength, elongation at break, tear strength, water absorption, shrinkage temperature, pH, and Fourier Transform Infrared Spectroscopy (FTIR) characteristics. The experimental leathers were subjected to physical and chemical analyses, and the obtained results were compared with recommended standards for vegetable-tanned upholstery leather [11]. The findings are expected to provide scientific evidence regarding the quality, performance, and sustainability potential of indigenous tanning practices in the Amhara region of Ethiopia.

EXPERIMENTAL

Materials

Cowhides: indigenous unhaired and hair-on tanned cowhide were sourced from the Amhara regional state of Bahir Dar city, ensuring similar quality and source.

Chemical Reagents: Distilled water, sulfuric acid concentration 98.3%, ammonia concentration 31%, sodium hydroxide solution concentration 50.5%, formic acid 85 %, and pH adjustment in certain reactions and analyses.

Methods

Using a random selection method, three full unhaired and three full hair-on leather pieces tanned through indigenous tanning method were collected from Amhara region in Bahir Dar city, then prepared for the required testing methods.

Organoleptic Properties Analysis of Indigenous Tanned Hides

Prior to physical testing, all leather specimens were conditioned according to ISO 2419 under standard atmospheric conditions of 23 ± 2 °C temperature and 50 ± 5% relative humidity for a minimum of 48 h.

Table 1: Testing Standards

Property	Standard
Sampling	ISO 2418
Conditioning	ISO 2419
Thickness	ISO 2589
Tensile strength and elongation	ISO 3376
Tear strength	ISO 3377-2
pH	ISO 4045
Shrinkage temperature	ISO 3380
FTIR	ASTM E1252 (or instrument protocol)

Thickness Test

The samples were tested and analyzed using the machine GT-313A1 thickness gauge with the samples prepared according to ES ISO 2589:2016 for both unhaired and hair-on indigenous tanned cowhide from the Amhara region of Bahir Dar City. For each type of unhaired and hair-on leather, three samples were taken. Five measurements were taken, distributed across a single sample and the average calculated to guarantee measurement accuracy and consistency.

Figure 1. Thickness measurement

Tensile Strength Test

Under room conditions, the tensile strength of both hair-on and hair-off indigenous tanned cowhide was measured by using an ASTM D2209 tensile testing machine with ISO 3376. For the physical test of the leather, test pieces were measured and cut from the sampling point perpendicular to and parallel to the backbone in the desired shape and size. Length A= 140, B= 50, C= 55, D= 20, R= 10; millimeters are used in the measurement. By dividing the breaking force in kilograms-force by the unstretched test piece's cross-section in square millimeters, the tensile strength was computed.

Figure 2. Measuring tensile strength (left); samples from unhaired traditional cowhide leather (center); samples from hair-on traditional cowhide leather (right)

Elongation

Leather elongation, like any material, is typically measured through a tensile test. This test stretches a sample with a controlled force until it breaks, recording the force and deformation (elongation) throughout the process.

$$\text{Elongation (\%)} = [(Lf - Li) / Li]*100 \qquad (1)$$

where: Lf is the final gauge length of the sample after fracture (mm); Li is the initial gauge length of the sample before testing (mm).

Tear Strength Test

An ASTM D2261 tear strength testing machine fitted with an ISO 3376 was used to measure the tear strength of both hairless and hair-on indigenous tanned cowhide. The test piece, measuring 75mm in length × 25 mm in width, is positioned perpendicularly and parallelly to the backbone of indigenous tanned cowhide leather. A 5 mm diameter hole was created on the midline and 25 mm from one end of each test piece.

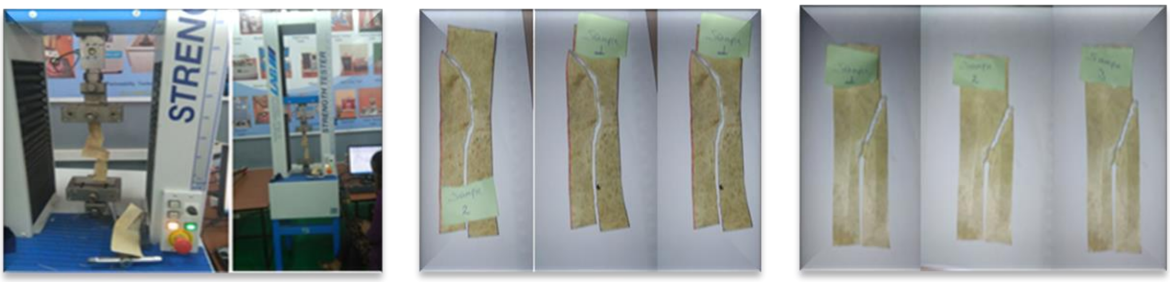

Figure 3. Measuring tear strength by ASTM D2261 (left); samples from unhaired traditional cowhide leather (center); samples from hair-on traditional cowhide leather (right)

Water Absorption

Water absorption in cowhide leather treated through indigenous method was measured using a gravimetric method BS 3144-SLP19 (IUP7), which is a 70mm circular cylinder cut from a glass vessel with a diameter over 80mm. A circular cylinder with a diameter of 70mm is cut from an unhaired and hair-on indigenously tanned cowhide and kept in a standard atmosphere at 27°C. The test piece is weighed to the nearest 0.01g and immersed in water at 27°C. After 2 hours, the weight is blotted and the percentage of water absorbed is calculated using the formula:

$$Q = 100(w1 - w0)/w0 \qquad (2)$$

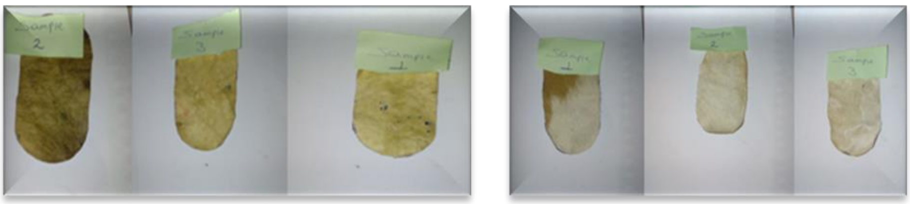

Figure 4. Water absorption test: unhaired traditional cowhide leather (left); samples from unhaired traditional cowhide leather (right)

Shrinkage Temperature

The shrinkage temperature of an unhaired and hair-on indigenous tanned cowhide strip was determined by using IS: 5914 – 1970. A 50 *3 mm rectangle of leather was cut from a specified location and then immersed in 10 ml of water. When a strip of leather is gradually heated in water, it undergoes sudden shrinkage at a temperature specific to tanning.

Figure 5. Unhaired and hair-on leather samples before shrinkage test, respectively

Figure 6. Unhaired and hair-on leather samples after shrinkage test, respectively

Chemical Property Analysis of Indigenous Tanned Leather

pH Test

The acidity and basicity of indigenous tanned leather were determined by using the IS 582[LC:18] – 1970 method. An amount of 5+ 0.1 g from the test portion is weighed and taken in a polyethylene flask bottle, and shaken well with 100 ml of water for 30 seconds to wet the ground leather uniformly. Then it was mechanically shaken in the shaker for 16 to 24 hours. The solution was filtered and pH was measured using pH meter HI-99171.

Figure 7. Measuring the pH of traditional unhaired and hair-on cowhide leather

Fourier Transform Infrared Spectroscopy

The Fourier Transform Infrared Spectroscopy of the leather sample was measured using FTIR machine L1600400 SPECTRA TWO DTGS were used for analyzing the chemical composition and structural characteristics. As per [12], using a scalpel and a sharp blade, the leather samples were scraped until they became thin. FTIR spectroscopy was used directly to evaluate the samples.

RESULTS AND DISCUSSION

Comparative Thickness of Indigenous with Modern Vegetable-Tanned Leather

Table 2 below shows that indigenous tanned cowhide leather with hair-on is thicker than indigenous tanned cowhide leather without hair. Every section of the particular sample of indigenous tanned cowhide leather has different thicknesses that have been noticed. It indicates that changes in thickness are due to non-uniform filling action of a tanning agent; although the thickness of the indigenous tanned cowhide leather meets the minimum necessary value, it is not consistently thick, according to the statistics below.

Table 2: Comparative thickness of indigenous with modern vegetable tanned leather

Comparative thickness (mm) value of leather tanned by ITL and MDTL						
	Unhaired			Hair-on		
Sample	1	2	3	1	2	3
ITL	1.17mm	1.26mm	1.54mm	1.70mm	1.57mm	1.47mm
Average	1.32mm			1.58mm		
Minimum recommended thickness value of vegetable-tanned leather (mm) MDTL						>0.5mm

Note: ITL - through the indigenous tanning method and MDTL - modern tanned leather

Tensile Strength of Indigenous Tanned Cowhide Leather

From Table 3 below the tensile strength of indigenous tanned cowhide hide leather without hair is 9.62 N/mm², which is less than the minimum recommended value of modern vegetable-tanned leather. The tensile strength of traditional cowhide hide leather with hair is 13.41 N/mm², which satisfies the minimum recommended value of modern vegetable-tanned leather >12 N/mm².

Table 3: Tensile strength of indigenous tanned cowhide leather

Tensile strength (N/mm²) value of leather tanned by ITL and MDTL						
	Unhaired			Hair-on		
Sample	1	2	3	1	2	3
ITL	9.32	16.77	2.77	8.93	15.61	15.70
Average	9.62 N/mm²			13.41 N/mm²		
Minimum recommended value of vegetable-tanned leather (N/mm²) MDTL						>12

Elongation at Break of Indigenous Tanned Cowhide Leather

Based on Table 4 below the elongation of unhaired indigenous tanned cowhide leather is 32.13%, while the elongation of hair-on indigenous cowhide leather is 12.47%. These values come up narrow of the minimum recommended value of vegetable-tanned leather >40%; however, the elongation of unhair indigenous cowhide leather is greater than that of hair-on indigenous cowhide leather. These findings demonstrate that indigenous tanned cowhide leathers, both hair-on, and hair-off, are more rigid and durable than modern vegetable-tanned leather and more challenging to stretch, wear, and penetrate. These results showed that unhaired and hair-on indigenous cowhide leathers are stiffer and tougher than modern vegetable-tanned leather and difficult to stretch, wear, and penetrate.

Table 4: Elongation at break of indigenous tanned cowhide leather

Elongation (%) value of leather tanned by ITL and MDTL						
	Unhaired			Hair-on		
Sample	1	2	3	1	2	3
ITL	31.6%	16.8%	48%	12%	12.8%	12.6%
Average	32.13%			12.47%		
Minimum recommended value of vegetable-tanned leather (%) MDTL						>40%

Tear Strength of Indigenous Tanned Cowhide Leather

The tests and data in Table 5 below show that the tear strengths of typical cowhide leathers, both hair-on and hair-off, are 80.33 N and 93.67 N, respectively. The tear strength of hair-on indigenous tanned cowhide leather is greater than that of unhaired indigenous tanned cowhide leather. However, the minimum suggested value of vegetable-tanned leather >20N is met by both hair-on and hair-off. These show that classic cowhide leather is robust, stiff, ductile, and sturdy.

Table 5: Tear strength of indigenous tanned cowhide leather

Tear strength (N) value of leather tanned by ITL and MDTL						
		Unhaired			Hair-on	
Sample	1	2	3	1	2	3
ITL	111	72	58	96	102	83
Average		80.33			93.67	
Minimum recommended value of vegetable-tanned leather (N) MDTL						>20

Water Absorption of Indigenous Tanned Cowhide Leather

The results observed and noted in Table 6 below show that after two hours, the water absorption of indigenous tanned cowhide leathers with and without hair is 207.47% and 235.50%, respectively. However, this does not meet the minimum suggested value of modern vegetable-tanned leather, which is less than 35%. The finding indicated that indigenous tanned cowhide leathers without hair absorb less water than those with hair, and that traditional tanned cowhide leathers have a higher water absorption capacity than modern vegetable-tanned leather.

Table 6: Water absorption of indigenous tanned cowhide leather

Water absorption (%) value of leather tanned by ITL and MDTL						
		Unhaired			Hair-on	
Sample	1	2	3	1	2	3
ITL	141.11	215.38	265.92	144.60	253.92	308.00
Average		207.47			235.50	
Minimum recommended value of vegetable-tanned leather (%) MDTL						<35%

Shrinkage Temperature of Indigenous Tanned Cowhide Leather

From Table 7 below the shrinkage temperature of indigenous tanned cowhide leather without hair is 54 °C, while the shrinkage temperature of leather with hair on is 50.33 °C. Traditional tanned cowhide leather does not meet the minimum recommended value of shrinkage temperature, compared to modern vegetable-tanned leather, which has a shrinkage temperature of >60 °C.

Table 7: Shrinkage temperature of indigenous tanned cowhide leather

Shrinkage temperature (°C) value of leather tanned by ITL and MDTL						
		Unhaired			Hair-on	
Sample	1	2	3	1	2	3
ITL	54	57	51	52	49	50
Average		54 °C			50.33 °C	
Minimum recommended value of vegetable-tanned leather (°C) MDTL						60 °C

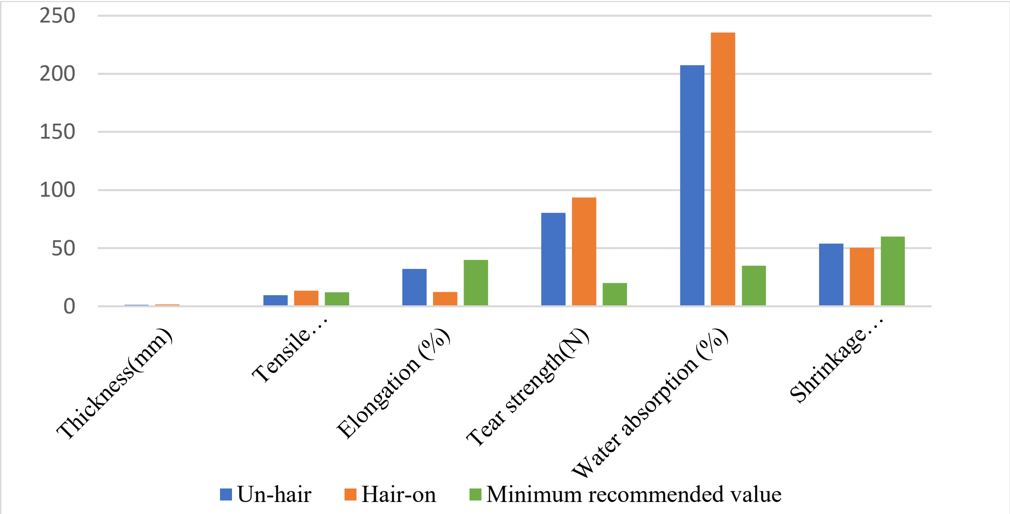

Figure 8. Diagrammatic representation of the physical properties of indigenous cowhides

pH of Indigenous Tanned Cowhide Leather

Table 8 indicates that the pH of indigenous cowhide leather without hair is 6.1 and that of indigenous tanned cowhide leather with hair is 6.6. These values are within the range of modern vegetable-tanned leather, without falling below 4 and the difference value not rising above 0.7. It is impossible to say whether tanned leather is better than hair-on indigenous cowhide leather, however, this suggests that unhaired indigenous cowhide leather is superior. According to the pH, indigenous cowhide leather is only tanned up to the point of pickling. Dyeing and fixing the colors is challenging at this pH level.

Table 8: pH of indigenous tanned cowhide leather

pH value of leather tanned by ITL and MDTL						
	Unhaired			Hair-on		
Sample	1	2	3	1	2	3
ITL	6.0	6.3	6.1	52	49	50
Average		6.1			6.6	
Recommended pH value of modern vegetable-tanned leather MDTL						Not below 4. Difference value not above 0.7

FTIR Test Result of Traditional Tanned Cowhide Leather

The FTIR spectra of indigenous tanned and modern vegetable-tanned cowhide leathers were analyzed to identify the functional groups associated with collagen structure and tannin–collagen interactions. The spectra were interpreted within four characteristic regions: the single-bond stretching region (2500–4000 cm^{-1}), the triple-bond region (2000–2500 cm^{-1}), the double-bond region (1500–2000 cm^{-1}), and the fingerprint region (600–1500 cm^{-1}).

The FTIR spectra of both indigenous and modern vegetable-tanned leathers exhibited characteristic collagen absorption bands. A broad absorption peak observed within the range of 3200–3400 cm^{-1} corresponds to O–H and N–H stretching vibrations associated with collagen molecules and phenolic compounds. The presence of absorption bands within 3200–3600 cm^{-1} indicates hydroxyl groups originating from vegetable tannins, suggesting successful penetration of tannin compounds into the collagen matrix. The absorption band near 1630–1650 cm^{-1} corresponds to the Amide I region and is attributed mainly to C=O stretching vibrations of collagen peptide bonds. Peaks observed around 1540–1555 cm^{-1} represent the Amide II band, arising from N–H bending and C–N stretching vibrations. Furthermore, the Amide III region was identified between 1230 and 1300 cm^{-1}, confirming the preservation of the collagen triple-helical structure after tanning. The fingerprint region (600–1500 cm^{-1}) contained several characteristic peaks related to collagen and tannin interactions, providing additional evidence of leather stabilization.

Compared with hair-on indigenous tanned cowhide leather and modern vegetable-tanned leather, the FTIR spectrum of unhaired indigenous tanned cowhide leather exhibited fewer peaks and lower absorption intensity within the single-bond, double-bond, triple-bond, and fingerprint regions. This suggests a lower degree of tannin–collagen interaction and a less extensive cross-linking network within the collagen structure. In contrast, hair-on indigenous tanned cowhide leather displayed a greater number of peaks and stronger absorption bands across these regions, indicating enhanced retention of functional groups and stronger molecular interactions. Differences in peak intensity between unhaired and hair-on indigenous leathers may be attributed to variations in tannin penetration, collagen stabilization, and the preservation of natural structural components during processing.

Overall, the FTIR results confirmed the presence of characteristic collagen amide bands and tannin-related hydroxyl groups in all leather samples. These findings demonstrate that indigenous tanning agents interact with collagen fibers through polyphenolic compounds, although the extent of stabilization appears lower than that observed in modern vegetable-tanned leather.

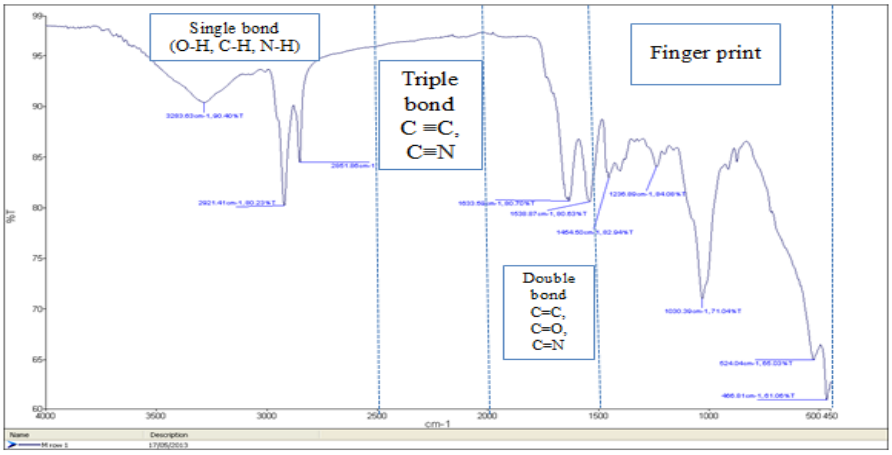

Figure 9. FTIR spectrum of unhaired traditional cowhide leather

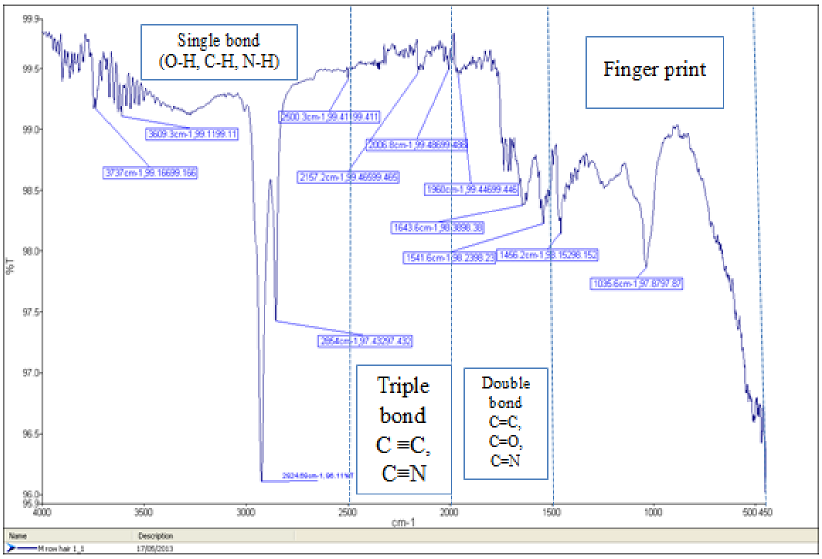

Figure 10. FTIR spectrum of hair-on traditional cowhide leather

FUTURE WORK

The author acknowledges the importance of Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), and water absorption kinetic studies. However, these analyses require specialized instrumentation that was not available during the present investigation. The recommendation has been incorporated into the Future Research section, where these techniques are proposed for further evaluation of thermal stability, cross-linking density, and moisture diffusion behavior of indigenous tanned leathers.

CONCLUSION

This study compared the physicochemical properties of unhaired indigenous tanned cowhide leather, hair-on indigenous tanned cowhide leather, and modern vegetable-tanned leather. The results revealed significant differences in the physical, chemical, and structural characteristics of the leather samples. The thickness values of unhaired and hair-on indigenous tanned leathers were 1.32 mm and 1.58 mm, respectively, exceeding the minimum recommended value for vegetable-tanned leather (>0.5 mm). Hair-on indigenous leather exhibited a tensile strength of 13.41 N/mm², satisfying the recommended minimum value (>12 N/mm²), whereas unhaired indigenous leather showed a lower tensile strength of 9.62 N/mm². The elongation at break values of both indigenous leathers (32.13% for unhaired and 12.47% for hair-on) were below the recommended value for vegetable-tanned leather (>40%).

Both unhaired and hair-on indigenous leathers demonstrated excellent tear strength values of 80.33 N and 93.67 N, respectively, considerably exceeding the minimum recommended value of 20 N. However, water absorption values were exceptionally high, reaching 207.47% for unhaired leather and 235.50% for hair-on leather after 2 h of immersion, indicating poor moisture resistance compared with modern vegetable-tanned leather (<35%). Similarly, the shrinkage temperatures of unhaired (54 °C) and hair-on (50.33 °C) indigenous leathers were lower than the recommended value for vegetable-tanned leather (>60 °C), suggesting lower hydrothermal stability and weaker collagen cross-linking. The pH values of both indigenous leathers (6.1 and 6.6) were within the acceptable range for leather materials.

FTIR analysis confirmed the presence of characteristic collagen absorption bands, including Amide I, Amide II, and Amide III, together with hydroxyl groups associated with vegetable tannins. Differences in peak intensity between unhaired and hair-on indigenous leathers indicated variations in tannin penetration and collagen stabilization. Hair-on indigenous leather exhibited stronger absorption bands and a greater number of spectral peaks, suggesting more extensive molecular interactions within the collagen matrix.

Overall, modern vegetable-tanned leather demonstrated superior tensile strength, elongation, hydrothermal stability, and moisture resistance. Nevertheless, indigenous tanned leathers exhibited acceptable thickness, tear strength, and near-neutral pH characteristics while utilizing locally available, biodegradable botanical tanning resources. Therefore, indigenous tanning represents a potentially sustainable and environmentally friendly alternative for traditional applications and selected low-performance leather products. Further studies employing advanced characterization techniques such as Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), and water absorption kinetics are recommended to better understand the thermal stability, cross-linking behavior, and moisture transport mechanisms of indigenous tanned leathers.

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