

Research Article

Preparation of Sheepskin Unhairing Extracts from Locally Available Plants: Cleaner Leather Processing

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Received 10 May 2022; Revised 1 August 2022; Accepted 9 August 2022; Published 31 August 2022

Academic Editor: Kevser Dincer

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Leather is made from animal hides and skins that have passed through several stages of processing, from soaking to finishing. Unhairing is a crucial processing stage in which hair is removed from the animal hide or skin through open up the hair and it facilitates subsequent operations. The conventional sodium sulfide-based unhairing process generates a high volume of effluent, which accounts for 50 to 70% of the total biochemical oxygen demand (BOD) and chemical oxygen demand (COD) load in the tanneries' effluent. This study aimed to investigate the potential of unhairing agents prepared from locally available plants. The research employed qualitative methods. Plant materials are collected, dried, and ground. In different proportions, unhairing extracts were obtained from *Phytolacca dodecandra* leaves, *Cucurbita foetidissima* fruits, and *Solanum incanum* fruits. In the conventional soaking process, plant extracts were applied in various concentrations to sheepskin. The physical parameters of conventionally processed (control) and experimentally treated leather were examined using FTIR, SEM, tear strength, percentage of elongation, and organoleptic tests. The unhairing solution was prepared from a mixture of 0.5% *S. incanum* extract, 0.5% *P. dodecandra* extract, 0.6% *C. foetidissima* extract, and 260 g/L lime powder lime, and this solution effectively removed the hair from the sheepskin in both hairs saving and hair burning unhairing process. The study revealed that the sheepskin treated with the plant extracts based on an unhairing agent and the conventional unhairing agent showed a comparable tensile strength (42.3 kg/cm and 45.2 kg/cm), tear strength (140.1 kg/cm² and 143.5 kg/cm²), and percent elongation at break (40.2 and 42.3), respectively, which were above the permissible limit for leather production making. According to the study findings, the plant extracts have a good potential for removing hair from sheepskin, and they are eco-friendly and cost-effective compared to unhairing chemicals such as sodium sulfide.

1. Introduction

Tanning is the process of conversion of animal hides and skins into finished leather. In Leather processing, animal skins or hide are passed through different processing stages including the beam house, tanning, post-tanning, and finishing operations. Unhairing is a crucial operation in leather processing that involves removing the hair or wool from the hide or skin. The conventional chemicals being used during

this operation are sodium sulfide, sodium hydrosulfide, lime, etc [1]. During the unhairing process, a reductive reaction was carried out. Hydrosulfide (HS⁻) and hydroxyl (OH⁻) ions disrupt the disulfide bridge of hair cysteine and convert it to cysteine, allowing for keratin hydrolysis (hair protein) [2].

The weakening of hair is dependent on the breakdown of the disulfide link of the amino acid cysteine, which is the characteristic of the keratin class of proteins that gives

strength to hair and wools. Keratin a fibrous protein typically makes up 90% of the dry weight of hair [3]. The hydrogen atoms supplied by the sharpening agent weaken the cysteine molecular link causing the covalent di-Sulphide bond linkages to rupture and weaken the keratin. To some extent, sharpening also contributes to unhauling, as it tends to break down the hair proteins [4, 5].

The conventional unhauling process in leather processing uses a lot of lime and sodium sulfide, which is hazardous and creates a lot of effluents. Under acidic conditions, sodium sulfide releases large amounts of hydrogen sulfide, which is a common source of fatal incidents [6]. Similarly, the conventional unhauling process emits a significant quantity of pollutants, including biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total solids (TS) [7].

Previously, several researchers attempted to mitigate the conventional unhauling-related problem by using plant-based and enzyme-assisted unhauling agents, which are environment-friendly options that decrease BOD and COD load in leather processing [1]. However, only a few plant-based and enzyme-assisted unhauling are performed in industrial applications, and currently, there is no commercially available environmentally friendly unhauling agent that can replace sodium sulfide [8, 9]. This research aimed to extract eco-friendly unhauling agents from locally accessible plants in order to minimize tannery effluent and replace conventional unhauling agents.

2. Materials and Methods

The study used both qualitative and quantitative approaches to assess the properties of plants and the tanned leather properties. The research experimental work has been carried out at the Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University, Ethiopia, and Bahir Dar Tannery, Ethiopia. The study data were analyzed by using tables, pictures, and graphs.

2.1. Plant Collection, Drying, and Grounding. *P. dodecandra* leaves, *S. incanum* fruit and *C. foetidissima* fruit were collected from the regions of Amhara and Oromia states, in Ethiopia. *P. dodecandra* leaves and *S. incanum* fruit was cleaned, washed repeatedly with water, and cut into small chips for faster drying. The plant parts were dried for five days at room temperature and oven-dried at 120°C for 2 h. Similarly, *C. foetidissima* fruit was cleaned, washed repeatedly with water, and cut into small chips for juice preparation. All plants selected for the experimental work were shown in Figure 1.

2.2. Plant Powder and Juice Preparation. *P. dodecandra* leaves and *S. incanum* fruit plant parts were individually weighed and ground in a high-speed multifunction grinder with a mesh size of 50–300. The reason behind grounding the plant parts was to maximize the surface area available for extraction, thereby raising the extraction rate. The powdered samples were placed in small plastic bags for further

experiment activity. Similarly, *C. foetidissima* fruit was cut into small pieces and the plant juice was prepared.

2.3. Extracts Preparation. In the study, separate extracts were obtained by mixing 0.5 kg *C. foetidissima* fruit sap, *P. dodecandra* leaves powder, and *S. incanum* fruit powder, and 80 mL of 99.5% methanol were used as a solvent. The plant extracts were prepared from each plant type in triplicate. The mixture was homogenized for 1 h using a magnetic stirrer at room temperature and the mixtures (juices) were separately filtered using a Whatman filter 1 paper, 15 cm disc. Each filtrate portion was then put in a glass beaker with aluminum foil on top and left to stand at room temperature for 48 h. The extracts were further purified using a centrifuge 5810 with 10,000 rpm centrifugation for 10 min at room temperature in order to remove insoluble materials. The filtrate was boiled in a water bath in order to evaporate the methanol and leave behind the extracts which was weighed and the percentage yield was calculated. The percentage of the plant fruit sap was calculated using the following method and their averages were used [10].

Fruits weight = Wf, Gross juice weight = Wj, Weight of the beaker = Wb, Net juice weight = Wb.

$$\text{Juice content} = \frac{\text{Net juice weight} \times 100}{\text{Fruit weight}}. \quad (1)$$

The pH of each extract was measured using a pH meter and their values were recorded. As shown in Figure 2, each extract was then preserved in volumetric flasks in a refrigerator at 4°C, for later experiment usage.

2.4. Yield Percentage of the *S. incanum*, *C. foetidissima*, and *P. dodecandra* Extracts. The amount of extracts from *S. incanum* fruits, *C. foetidissima* fruits, and *P. dodecandra* will depend on the plant age, growing geography, and methods of extraction. The amount of each plant extract was indicated in the following Table 1.

2.4.1. Phytochemical Tests. The plant extract was subjected to preliminary qualitative phytochemical screening for steroids, alkaloids, flavonoids, tannins, saponins, and phenol-based on the following standard methods.

2.4.2. Test for Flavonoids. The alkaline reagent test method was used to detect the presence of flavonoids in the extracts. A small amount of extract was treated with aqueous NaOH and HCl and observed for the formation of the yellow-orange color [11].

2.4.3. Test for Alkaloids. Mayer's reagent test method was used to process the extracts (1.36 g of mercuric chloride and 5 g of potassium iodide in 100 ml of water). The presence of alkaloids is indicated by the formation of a yellow-colored precipitate [12].



FIGURE 1: (a) and (b) (buffalo guard fruit and seed), (c) *P. dodecandra* leaves, and (d) Sodom apple fruits.

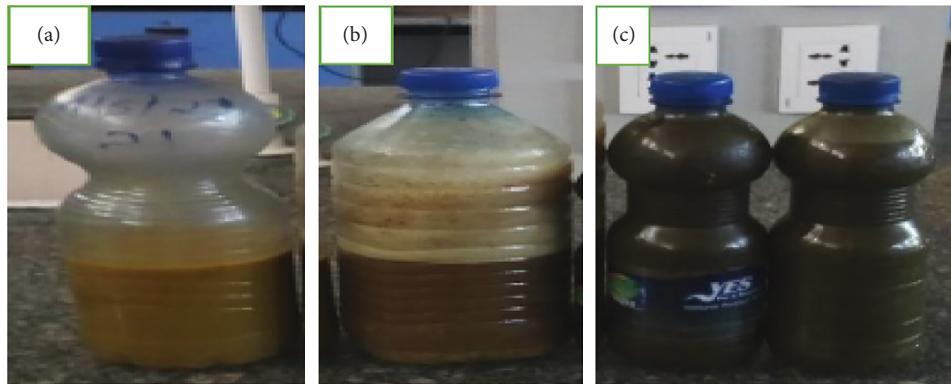


FIGURE 2: (a) *S. incanum* fruit extract. (b) *C. foetidissima* fruits extract. (c) *P. dodecandra* leaves extract.

TABLE 1: Yield percentage of the plants extracts.

Types of plants used	Amount of raw plant taken for extraction (kg)	Amount of extract (kg)	Yield percentage (%)
<i>S. incanum</i>	0.5	0.25	50
<i>C. foetidissima</i>	1	0.6	60
<i>P. dodecandra</i>	0.75	0.5	75

2.4.4. Test for Phenolic Compound. Ferric chloride test method was used to detect the presence of phenolic compounds in the extracts. A 3–4 drops of 5% ferric chloride solution were added to the extracts. The presence of phenols is indicated by the formation of a bluish-black color [13].

2.4.5. Test for Saponins. The Froth test method was used to detect the presence of saponin in the extracts. A 0.5 gm of extracts were mixed with 2 ml of water and shaken for 15 minutes in a graduated cylinder. The presence of saponins is shown by the formation of a 1 cm layer of foam [14].

2.4.6. Test for Tannins. Ferric chloride test method was used to detect the presence of tannin in the extracts. A 0.5 g of crude of each plant extract was mixed with 10 mL of distilled water and boiled and then filtered. Three drops of 0.10% ferric chloride were added to the filtrate. The formation of brownish, greenish, or blue-black color was an indication of the presence of tannins [14].

2.4.7. Test for Steroid. Chromatographic test method was used to detect the presence of steroids in the extracts. A 1 ml of the plant extract was added to 1 ml of concentrated

tetraoxosulphate (VI) acid (H_2SO_4). A red coloration confirmed the presence of steroids [13].

2.5. Experimental Hypothesis: Optimization of Unhairing Agents for Experiments. In the study, unhauling of sheepskin was conducted by the mixture of extracts unhauling solutions prepared from *P. dodecandra* leaves extract, *C. foetidissima* fruits extract and *S. incanum* fruits extract. Initially, the sheepskin was treated with conventional soaking agents (i.e., water and wetting agents) in order to rehydrate the skin, and then the unhauling extracts were applied to the skin. The reaction of a solution occurred at a low temperature. In order to obtain the optimum effective unhauling ratio, three experiments were carried out under different parameters, which are shown in Tables 1–3.

2.6. Preparation of Unhauling Extract Solution. Based on the unhauling recipe indicated in Tables 2–4, a 400 mL separate unhauling solution was prepared by mixing *S. incanum* extract, *P. dodecandra* extract, and *C. foetidissima* extract. After mixing the solution, 260 g/L of lime powder was added and stirred. The biome of the solution was checked. The prepared unhauling solution was kept for 24 h in order to enhance the solution mixture uniformity. The prepared

TABLE 2: The mixing ratio of each plant extract for Experimental trial 1.

Experimental Trial—1					
Skin types	Temp (°C)	Time (h)	Mixing ratio (<i>S. incanum</i> , <i>P. dodecandra</i> , <i>C. foetidissima</i> and lime powder)	Salt amount (Be)	pH
Wet salt	25	4	0.5, 1, 0.3 and 260 g/L	7.5	9.5
	25	4	0.6, 1, 0.3 and 260 g/L	7.5	9.5
	25	4	0.7, 1, 0.3 and 260 g/L	8	9.5
	25	4	0.5, 0.5, 0.6 and 260 g/L	10	10

unhairing solution was applied to sheepskin using two different methods: a hair-saving method on the flesh side of the skin and a hair-burning method using a drum.

2.7. Preparation of Soaking Recipe for Unhairing Process through Hair-Saving Method. Purification and defects-free raw sheep skin were used. The sheepskin soaking process was carried out by preparing a soaking recipe for the hair-saving method, as shown in the following Table 5.

2.8. Application of Conventional Unhairing through Painting Method (Control). Based on the recipe indicated in Table 5, half-side of the sheepskin was soaked in the soaking solution. Then, the skin was weighed and painted with a paste containing 10% lime, 2% sodium sulfide, 15% water, and 0.2% wetting agent. The paint was applied on the flesh side of the skin. Then, the treated sheep skin was covered well with wet gunny cloth and was kept in pile flesh to flesh for 5-6 h. Lastly, unhairing was carried out using mechanical action by using a dull knife.

2.9. Application of Experimental Unhairing through Painting Method (Experiment). Based on the recipe indicated in Table 6, half-side of the sheepskin was soaked in the soaking solution. Then, the skin was weighed and painted with a solution containing *S. incanum*, *P. dodecandra* extract, *C. foetidissima* extract, and lime powder, which were indicated in Table 1. The paint was applied on the flesh side of the skin and piled for 5-6 h by the flesh to flesh side and grain to the grain side. Lastly, unhairing was carried out using mechanical action by using a dull knife. After the soaking process was completed liming was carried out.

2.10. Preparation of Sheepskin for Unhairing Process through Hair-Burning Method. In the study, purification and defects-free raw sheepskin were used. The soaking process was carried out by preparing a soaking recipe prepared for hair-burning method, as shown in Table 7.

2.11. Application of Conventional Unhairing through Hair-Burning Method (Control). The hair-burning process was carried out in the drum according to the recipe shown in Table 6. A half-sheep skin was soaked in the drum containing 300% water, 5% lime, and 3% sodium sulfide. Then, the drum was run for 10 min within 2 h and left overnight. By the next day, the skins were unhaired and re-limed for a day with a solution containing 5% lime ad 0.2% caustic soda.

When the sheep's skin were properly plumped, they are taken for unhauling and fleshing processes. Drums are used to accelerate the liming process and the rpm of the drum was set to 2-3 in order to avoid too much beating action. Completion of the liming process was decided by the characteristics desired in the final leather as well as the raw materials from which they are produced.

2.12. Application of Experimental Unhairing through Hair-Burning Method (Experimental). The experimental unhauling (hair burning) was carried out in the drum according to the recipe indicated in Table 8.

3. Results and Discussion

3.1. Phytochemical Analysis of Plants Extracts. Different studies revealed that the presence of bioactive compounds in the plant has a significant antimicrobial activity, which may enhance the quality of the leather treated with the plant extracts. As shown in Table 9, the *S. incanum* fruits extracts, *C. foetidissima* fruits extracts, and *P. dodecandra* leave extracts showed the presence of some bioactive compounds.

3.1.1. Flavonoids Detection. Alkaline reagent test revealed a strong positive (++) presence of flavonoids only in *S. incanum* extract, as shown in Table 9. The present study investigation was similar to that of Lin et al. and Sbhatu et al [15, 16], who reported the presence of flavonoids in *S. incanum*.

3.1.2. Saponins Detection. The Froth test approach revealed the existence of strong positive (++) saponins in the extracts of *S. incanum*, *C. foetidissima*, and *P. dodecandra*, which were shown in Table 9. Correspondingly, different studies revealed the presence of saponins in the extracts of *S. incanum* [17, 18], extracts of *C. foetidissima* [19, 20], and extracts *P. dodecandra* [21, 22].

3.1.3. Phenols Detection. As indicated in Table 9, the ferric chloride test revealed the presence of a strong positive (++) phenols in the extracts of *S. incanum*, *C. foetidissima* and *P. dodecandra*. Similary, Prohens et al. and Belayneh et al. [23, 24] reported the presence of phenols in *S. incanum*, Salehi et al. [20] reported the presence of phenols in *C. foetidissima* and Makonnen et al. and Namulindwa et al. [25, 26] reported the presence of phenols in *P. dodecandra*.

TABLE 3: The mixing ratio of each plant extract for Experimental Trial 2.

Experimental Trial—2						
Skin types	Temp (°C)	Time (h)	Mixing ratio (<i>S. incanum</i> , <i>P. dodecandra</i> , <i>C. foetidissima</i> and lime powder)	Salt amount (Be)	pH	
Wet salt	30	4	1, 0.5, 0.3 and 260 g/L	7.5	9.5	
	30	4	1, 0.7, 0.3 and 260 g/L	7.5	9.5	
	30	4	1, 0.8, 0.6 and 260 g/L	8	9.5	
	30	4	0.5, 0.5, 0.6 and 260 g/L I	10	10	

TABLE 4: The mixing ratio of each plant extract for Experimental Trial 3.

Experiment Trial—3						
Skin types	Temp (°C)	Time (h)	Mixing ratio (<i>S. incanum</i> , <i>P. dodecandra</i> , <i>C. foetidissima</i> and lime powder)	Salt amount (Be)	pH	
Wet salt	35	3	0.5, 1, 0.3 and 260 g/L	8.5	8.5	
	35	3	0.6, 1, 0.3 and 260 g/L	7.5	8.5	
	35	3	0.7, 1, 0.6 and 260 g/L	8	9	
	35	3	0.5, 0.5, 0.6 and 260 g/L	9.5	9.5	

TABLE 5: Soaking recipe for unhauling process through hair-saving method.

Soaking recipe for hair-saving method						
Process	Weight (%)	Weight (kg/L)	Chemical	Time (minute)	Temp (°c)	pH
Pre-soaking	300	3	Water	10	25	8.5
	300	3	Water	10		
	300	3	Water	30		
Main-soaking	0.5	0.05	Wetting agents	O/N	9	9
	1	0.05	Soda ash			
	1	0.5	Buzume 1448			

TABLE 6: Soaking recipe for unhauling process through painting method.

Process	Weight (%)	Chemical	Temp (°C)	Time	pH
Dirt wash	150	Water	60	30–60 minute	
	120	Water			
Immunise	1.6	Extracted unhauling agents and	60	3-4 hr.	4.5–5
	1.5	Lime agent			

TABLE 7: Conventional recipes for the unhauling process (Hair-burning method).

Conventional recipes for unhauling process						
Process	Weight (%)	Weight (kg/L)	Chemical	Time (minutes)	Temp (°C)	pH
Pre-soaking	300	3	Water	10'	25	8.5
	300	3	Water	10'		
	300	3	Water	10'		
Main-soaking	0.5	0.05	Wetting agents	O/N	9	2-3
	1	0.05	Soda ash			
	1	0.5	Buzume 1448			
	300	3	Water			
Liming	5	0.15	Lime	Run 10 min every 2 h, and left overnight.	11	2-3
	3	0.09	Sodium sulfide			
	5	0.05	Lime			
	0.1	0.1	Caustic soda			

3.1.4. Alkaloids Detection. As shown in Table 9, Mayer's and Wagner's tests revealed the presence of strong positive (++) alkaloids in the extracts of *S. incanum*, *C. foetidissima* and

P. dodecandra. Related findings by Eltayeb et al. and Desta et al. [27, 28] reported the existence of alkaloids in *S. incanum*, Ferguson [29] reported the existence of alkaloids

TABLE 8: Experimental recipes for the soaking process (Hair-burning method).

Weight	%	Weight (kg/l)	Chemical used	Temp (°C)	Time (minute)	pH
Pre-soaking	300	3	Water	Room temp.	10'	
	3000	3	Water		10'	
	"	"	"		10'	
Main-soaking	300	3	Water	30'	30'	
	0.5	0.05	Wetting agent		O/N	8-9

TABLE 9: Types of Phytochemicals found in extracts of *S. incanum* fruits, *C. foetidissima* fruits, and *P. dodecandra* leaves.

No	Compound	Detection method	Phytochemicals		
			<i>S. incanum</i>	<i>C. foetidissima</i>	<i>P. dodecandra</i>
1	Flavonoids	Alkaline reagent test	++	—	—
2	Saponins	Froth test	++	++	++
3	Phenols	Ferric chloride test	++	++	++
4	Alkaloids	Mayer's and Wagner's test	++	++	—
5	Tannins	Ferric chloride test	++	++	++
6	Steroids	Chromatographic test methods	++	++	++

Key: (-): Not detected, (+): Weak positive test and (++) Strong positive test.

in *C. foetidissima* and Ongutu et al. and Namulindwa et al.[26, 30] reported the existence of alkaloids in *P. dodecandra*.

3.1.5. Tannin Detection. In ferric chloride test, a strong positive (++) tannins were detected in *S. incanum*, *C. foetidissima* and *P. dodecandra*, which were shown in Table 9. Correspondingly, Sahle, Okbatinsae et al. and Desta et al. [28,31] reported the presence of tannins in *S. incanum* extracts, Salehi et al. and Pámanes et al. [20, 32] reported the presence of tannins in *C. foetidissima* and Namulindwa et al. [26] reported the presence of tannins in *P. dodecandra*.

3.1.6. Steroids. The chromatographic test approach detected the presence of strong positive (++) steroids in *S. incanum*, *C. foetidissima*, and *P. dodecandra*, which were indicated in Table 9. Correspondingly, Ferguson [29] revealed the existence of steroids in *S. incanum* and *C. foetidissima*, and Ongutu et al. and Namulindwa et al. [26, 30] revealed the existence of steroids in *P. dodecandra*.

3.2. Unhairing Effectiveness of the Plants Extracts. The unhauling experiment was carried out with different mixing ratios of *S. incanum* extract, *P. dodecandra* extract, *C. foetidissima* extract, and lime powder under different temperatures, times, and pH values.

Experimental trial 1 was conducted under a constant temperature (25°C), Time (4 h), and lime powder (260 g/L) with a variable ratio of plant extracts. In the current study, the level of unhauling efficiency was judged by subjective by looking at the treated skin carefully. A high level of unhauling indicates that the hair was completely removed from the sheep skin, medium level of unhauling indicates that the hair was removed to some extent whereas low level of unhauling level indicates the hairs were removed in a low extent. As indicated in Table 10, the unhauling mixture ratio of 0.5 *S. incanum*, 0.5 *P. dodecandra*, 0.6 *C. foetidissima* and

260 g/L lime powder resulted in high level of unhauling effectiveness compared to the other experimental trials. As shown in Table 10, when the unhauling extracts mixing proportions were close to each other (0.5, 0.5, 0.6), the effectiveness of unhauling was enhanced.

In the study, Experimental Trial 2 was conducted under a constant temperature (30°C), Time (4 h) and lime powder 260 g/L. As indicated in the above Table 11, the unhauling mixture ratio of 0.5 *S. incanum*, 0.5 *P. dodecandra*, 0.6 *C. foetidissima*, and 260 g/L lime powder resulted in high level of unhauling effectiveness compared to the other experimental trials. Similar to Experimental Trial 1, when the mixing proportion of the extracts was close to each other and the effectiveness of unhauling were enhanced, which were shown in Table 11.

Experimental Trial 3 was conducted under a constant Temperature (35 C), Time (3 h) and lime powder 260 g/L. As indicated in Table 12, the mixture of 0.5 *S. incanum*, 0.5 *P. dodecandra*, 0.6 *C. foetidissima* and 260 g/L lime powder resulted in high level of unhauling compared to the other experimental trials. As indicated in Table 11, when the mixing proportion of the extracts was close to each other and the efficiency of unhauling was enhanced. Based on three Experimental trial results, it is observed that the unhauling mixture ratio of *S. incanum*, 0.5 *P. dodecandra*, 0.6 *C. foetidissima* and 260 g/L lime powder resulted in a high level of unhauling effectiveness. In the three experimental trials, varying the Temperature (25 C, 30 C, and 35 C) and Time (3 h and 4 h) has not affected the unhauling extracts' hair removal effectiveness.

3.3. FTIR Analysis. Fourier transforms infrared (FTIR) spectroscopy is an important technique used for the chemical analysis of biological substances. Based on this, the raw sheepskin, experimentally unhaired sheep skin and conventionally unhaired sheep skin were characterized using in order to determine the sheep skin relative functional

TABLE 10: The plants unhauling extracts effectiveness under Experimental Trail 1.

Skin type	Temp. (°C)	Time (h)	Experimental Trial-1		pH	Unhauling level (low, medium, and high)
			Mixing ratio (<i>S. incanum</i> extract, <i>P. dodecandra</i> extract, <i>C. foetidissima</i> , and lime powder)	Salt amount (Be)		
Wet salt	25	4	0.5, 1, 0.3 and 260 g/L	7.5	9.5	Low
	25	4	0.6, 1, 0.3 and 260 g/L	7.5	9.5	Low
	25	4	0.7, 1, 0.3 and 260 g/L	8	9.5	Low
	25	4	0.5, 0.5, 0.6 and 260 g/L	10	10	High

TABLE 11: The plants unhauling extracts effectiveness under Experimental Trail 2.

Skin types	Temp. (°C)	Time (h)	Experimental Trial—2		pH	Unhauling level (low, medium, and high)
			Mixing ratio (<i>S. incanum</i> , <i>P. dodecandra</i> , <i>C. foetidissima</i> , and lime powder)	Salt amount (Be)		
Wet salt	30	4	1, 0.5, 0.3 and 260 g/L	7.5	9.5	Low
	30	4	1, 0.7, 0.3 and 260 g/L	7.5	9.5	Medium
	30	4	1, 0.8, 0.6 and 260 g/L	8	9.5	Medium
	30	4	0.5, 0.5, 0.6 and 260 g/L	10	10	High

TABLE 12: The plants unhauling extracts effectiveness under Experimental Trail 3.

Skin types	Temp. (°C)	Time (h)	Experiment Trial - 3		pH	Unhauling level (low, medium, and high)
			Mixing ratio (<i>S. incanum</i> , <i>P. dodecandra</i> , <i>C. foetidissima</i> and lime powder)	Salt amount (Be)		
Wet salt	35	3	0.5, 1, 0.3 and 260 g/L	8.5	8.5	Low
	35	3	0.6, 1, 0.3 and 260 g/L	7.5	8.5	Medium
	35	3	0.7, 1, 0.6 and 260 g/L	8	9	Medium
	35	3	0.5, 0.5, 0.6 and 260 g/L	9.5	9.5	High

group. The raw skin experimentally treated skin and conventionally treated skin FTIR% Transmittance vs wavelength (cm^{-1}) result images were shown under Figures 3–5.

As shown in Figures 3–5, there is a huge difference between raw skin, treated and conventional treated leather. Similarly, there was a difference between conventional and experimental treated leather that reveal a broad band in the range of $3550\text{--}3150 \text{ cm}^{-1}$. Raw skin has more single bond, double bond, triple bond, and fingerprints and also has more peaks than experimental treated and conventionally treated leather. The FTIR spectra of untreated raw skin were shown in Figure 3.

The FTIR spectra of Experimentally Treated Leather were shown in Figure 4.

The FTIR spectra of conventionally Treated Leather were shown in Figure 5.

3.4. Comparison of Sheep Skin Treated with Experimental and Conventional Unhauling Agents. The main objective of unhauling were to remove hair from sheepskin. The weakening of the hair depends on the breakdown of the disulfide link of the amino acid and cystine. The experimental and the conventional unhauling process result has been discussed as follows.

3.5. Experimental Unhauling through Hair Saving Method Result Analysis. In the experimental saving (painting) process, the sheepskin was treated with a 400 mL

unhauling containing a mixture of extracts of 0.5% *S. incanum* extract, 0.5% *P. dodecandra* extract, 0.6% *C. foetidissima* extract, and 260 g/L lime powder. This unhauling process was resulted in complete removal of hair from sheep skin after exposure of 3–4 h and 25–30°C. The unhauling agent extracted from the plant extracts not only removed the hair but also makes the sheep's skin clean and swell up. The plant-based unhaired sheep skin was to some extent similar to conventionally unhaired sheep skin. Sheepskin before treatment and sheep skin after treatment with unhauling through the hair-saving method was shown in Figure 6.

3.6. Experimental Unhauling through Hair Burning Method Result Analysis. In the hair burning experiment, the sheep skin was treated with a 400 mL solution containing an extract mixture of 0.5% *S. incanum* extract, 0.5% *P. dodecandra* extract, 0.6% *C. foetidissima* extract, and 260 g/L lime powder has resulted in complete removal of hair from sheep skin after exposure of 12 h on a drum, which is indicated in Figure 7.

In the current study, the unhauling solution was prepared from a mixture of 0.5% *S. incanum* extract, 0.5% *S. incanum* extract, 0.5% *P. dodecandra* extract, 0.6% *C. foetidissima* extract and 260 g/L lime powder have effectively removed the hair from the sheepskin in both Hairs-saving and Hair-burning unhauling process.

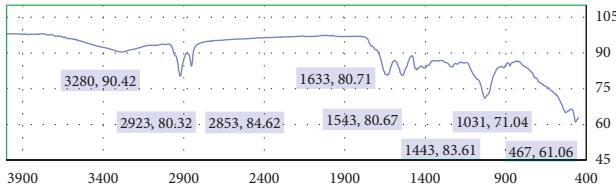


FIGURE 3: The FTIR spectra of untreated raw sheep skin.

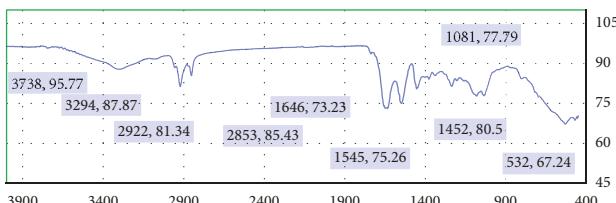


FIGURE 4: The FTIR spectra of experimentally treated sheep skin.

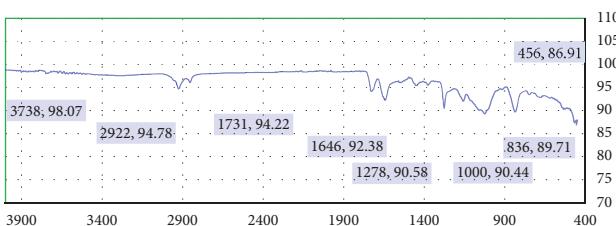


FIGURE 5: The FTIR spectra of conventionally treated sheep skin.

According to different studies, *P. dodecandra* fruits and *S. incanum* are rich in detergent agents namely saponins, which resulted in a clean leather, reduced smell, and substantially reduced amount of load released on the environment such as sulfide, nitrogen, carbon-oxygen demand.

According to different literatures, the presence of calcium thioglycolate in *S. incanum*, the presence of zinc in *C. foetidissima* (pumpkin), and the presence of saponified (antimicrobials) in *P. dodecandra* leaves have resulted in the breakdown of disulfide bond in keratin and fiber open up. Correspondingly, the presence of lime in the unhairing agent enhanced the hair removal effectiveness from sheep skin. On the other hand, the experimental plant-based unhairing extract has the ability to reduce bacterial attacks and also acts as a preservative in the leather. Therefore, this study clearly indicates that the unhairing solution prepared from the plants has a good potential to replace the conventional sodium sulfide-based unhairing and liming process in the leather industry.

3.7. Physical Test Analysis of Experimentally and Conventionally Treated Sheep Leather. The physical test analysis was carried out after sheepskin was treated with experimental and conventional unhairing recipes/. After the unhairing process, the sheepskins were passed through a similar leather processing stages. The final leathers were tested and their physical test results are presented in Figure 8.

3.8. Tear Strength Determination. Tear strength test methods were intended for the determination of load in kg required to

tear the test sample. Tear strength testing was carried out according to ISO 3376: 2011 and ASTM D2209—00 (2015) test methods. As indicated in Table 6, the sheepskin treated with the experimental extracts and conventional solution showed a comparable tensile strength (42.3 kg/cm) with conventionally unhaired leather (45.2 kg/cm), which was above the permissible limit for leather production making.

3.9. Tensile Strength Determination. Tensile strength test methods were intended for the determination of tensile strength, temporary and permanent elongation at specified load, modulus, and elongation at break of sheep leather. The treated sample pieces were prepared according to ISO 3376: 2011/ASTM D2209 - 00(2015). As indicated in Figure 6, the study result indicates that the leather treated with plant unhairing extracts has a comparable tensile strength (140.1 kg/cm² and 143.5 kg/cm²) and percent elongation at break (40.2 and 42.3), which were above the permissible limit for leather production making.

3.10. Grain Crack Strength Load and Grain Crack Strength Distention. Consequently, the study revealed that the sheep skin treated with the experimental unhairing extracts and conventional solution showed a comparable Grain Crack Strength load (23 kg and 23.2 kg) and Grain crack strength distention (11.2 mm and 11.65 mm), which were above the permissible limit for leather production making.

3.11. Organoleptic Property Comparison of Experimentally and Conventionally Treated Leather. Organoleptic property was carried out by nine experienced leather technologists working at an industry level and the average response were taken. As indicated in Figure 9, the organoleptic property of comparison between the conventional and experimental treated leather evaluation highest scores out of 9. The score result strength increases from 1 to 9. In the leather, the technologist response indicated that the conventionally treated leather and experimentally treated leather had the same result on grain pattern, uniformity of color, and fullness, however, they have a difference in feel and general appearance. The experimentally treated leather has shown a better feel and general appearance than the conventionally treated leather.

3.12. Pollution Load Analysis. As indicated in Figure 10, the use of unhairing agents extracted from locally available plants resulted in a reduction in pollution loads such as BOD, COD, TDS, and TSS in comparison with the conventionally treated sample. The conventionally treated sample showed more amounts of pollution loads in the unhairing process. This study revealed that the experiment treated sheep skin resulted in a COD, BOD, TDS, and TSS load of 62.7, 79, 81.8, and 27.2%, respectively. The experimental treated skin also shows complete unhairing along with a 59.3% reduction in the suspended solids level.

Keys: COD: chemical oxygen demand; TDS: total dissolved solid; ppm e parts per million.



FIGURE 6: Unhairing using plant extracts via Hair Saving method (a) Sheep skin before treatment (b) Sheep skin after treatment.

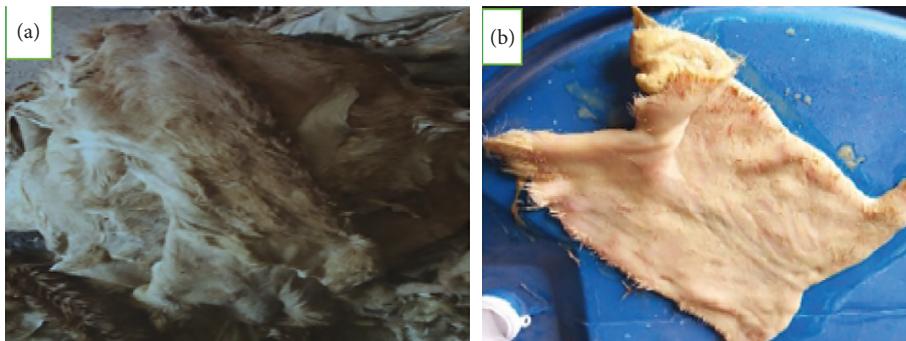


FIGURE 7: Unhairing using plant extracts via hair burning method (a) Sheep skin before treatment (b) Sheep skin after treatment.

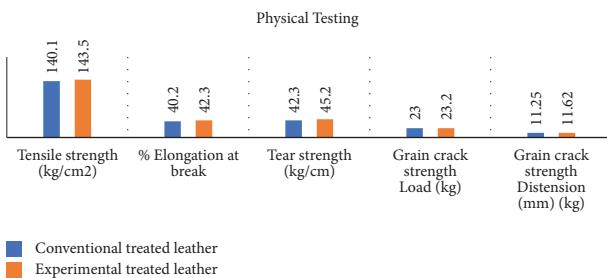


FIGURE 8: Physical properties of the conventionally treated and experimentally treated sheep Leather.

Conventionally & Experimentally Treated Leather

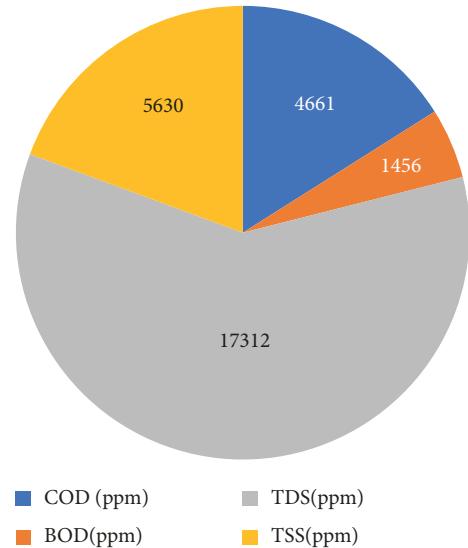


FIGURE 10: Pollution load of conventional and experimentally treated process.

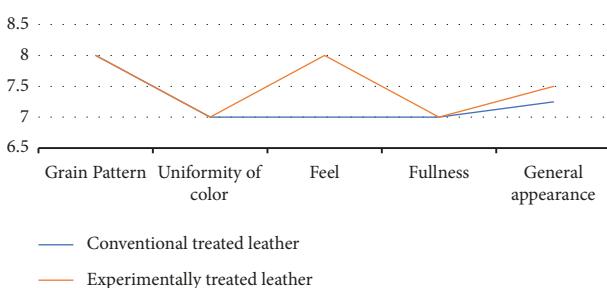


FIGURE 9: Comparision of organoleptic property of conventional and experimentally treated leather.

3.13. SEM Analysis. To study the effect of the unhairing agents on the structural characteristics of the crust leather, scanning electron microphotographs were used to analyze the effect of experimentally treated and conventionally

treated on the crust. The SEM analysis was carried out using FEI-Quanta 200 scanning electron microscope based on the following SEM standards.

In the study, the grain surfaces and the cross-section image of conventionally treated and experimental treated sheep skin crust were analyzed using Scanning Electron Microscope. As shown in Figure 11, it s observed that the

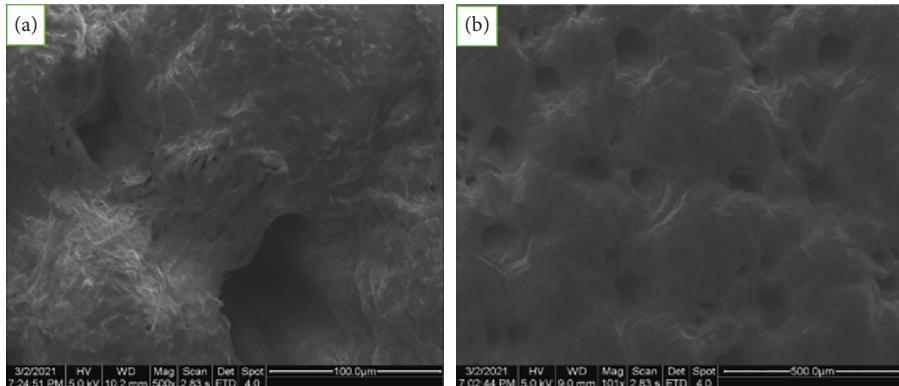


FIGURE 11: SEM analysis. (a) Conventionally treated leather. (b) Experimentally treated leather.

experimentally treated crust grain surface appears to be more even, open up, and smoother than the conventionally treated leather. Likewise, the experimentally treated crust pores are free of any hair residues and the fiber of collagen was more open than conventionally treated leather.

4. Conclusion

Extracted unhairing agents from locally available have a potential of removing hair from sheepskin. The current study result revealed the possibility of eliminating pollution-causing chemicals such as sodium sulfide, lime, and sodium sulfide in the unhairing process. Consequently, the unhairing agent prepared from the plant source not only eliminated sulfide but also enhanced the softness and quality of the final leather. The current study resulted in the treated leather being knit, clean, and reduced the pollution load on the environment. Since lots of plant species are available in the world, the potential of related plant species for an unhairing agent needs to be studied in the future.

Data Availability

The data collected and analyzed during this study are included in the paper and can also be accessed from the authors through a rational request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All the authors have contributed to the conceptualization, investigation, data collection, and analysis in the study and have read and approved the final manuscript.

Acknowledgments

The authors would like to acknowledge the Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University, for the financial and laboratory facilities support in successful completion of the research work. The authors also

would like to thank Ethiopian Leather Industry Development Institute for the laboratory facilities support.

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