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Research Article

Vegetable Tannins as Chrome-Free Leather Tanning

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The purpose of this study is to replace chrome tannins with ecofriendly vegetable tannins as an alternative solution to prevent the public health and the environmental pollution. Vegetable tannin was extracted from *Cassia singueana* bark using an aqueous extraction method and applied on sheep pickle pelt. Optimum tannin extraction parameters were identified at powder concentration of 80 g/L, extraction temperature of 100°C, and extraction time of 120 mins. Chemical functionality of *Cassia singueana* extracted tannins was evaluated via FT-IR spectroscopy. Hence, the FT-IR spectrum confirmed the presence of wide band of phenolic hydroxyl (OH^-) and carboxyl (C-O) groups connected with the aromatic ring. Moreover, physicochemical performance of the *Cassia singueana* extract tanned leather sample was scientifically examined and showed comparable results to conventional Mimosa tanned leather sample. The shrinkage temperature of *Cassia singueana* extract tanned leather recorded 83°C which is slightly higher than that of Mimosa extract (standard), 80°C. The results of mechanical properties such as tensile strength, tear strength, and elongation at break of *Cassia singueana* extract tanned leather sample are 15.6 N/mm^2, 24.2 N/mm, and 45.3%, respectively, which are relatively higher than those of Mimosa extract tanned leather sample. A relatively higher reduction level of pollution load (BOD, COD, and TDS) was observed in the wastewater released from *Cassia singueana* bark extract compared to the Mimosa extract (standard). Finally, findings from this study revealed that *Cassia singueana* bark extract could be considered as an alternative source of vegetable tannins to reduce the consumption of chrome tanning in the leather tanning industry.

1. Introduction

Leather production is the earliest technology that has been termed man's first manufacturing process [1, 2]. It involves the conversion of raw animal hides and skin into a valuable leather material. It shows enhanced property of thermal stability, abrasion, and water penetration due to the reaction between reactive functionalities of tannins and collagen protein of skins and hides [3]. Tanning is a process of treating skins and hides with organic or inorganic chemicals to produce a leather product with improved softness, antimicrobial properties, strength, heat resistance, and stable structure [4]. This process is considered as a major process in leather production which comprises of further chemical reactions and mechanical actions.

Before the 19th century, traditional tanneries used organic compounds obtained from roots, leaves, barks, and wood of different plants as tannins to convert skin to leather [2, 5]. This vegetable tanning process has been developed in the Mediterranean region [6] and practiced for centuries mainly in Europe until the end of the 19th century [2, 7]. After the 19th century, vegetable tanning has been gradually replaced by chemical tanning. Chrome tanning is the most extensively used in the global leather manufacturing industry [8] which contributes about 90% of the total tanning consumption worldwide. It provides excellent features such as thermal stability and physical properties to leather product [9–14].

However, chrome (Cr_{VI} and Cr_{III}) compounds in leather tanning produce huge amount of chrome-containing waste, which is openly disposed to the environment and leads to various health and environmental concerns and disorders [15–18]. Chromium-rich solid and liquid wastes can affect the human and animal respiratory organs, skin, liver, and kidneys. It can also cause cancer and infertility [19].

Considering the negative impact of chrome tanning, many researchers are exploring sustainable and green manufacturing processes by using alternative environmentally friendly chrome tanning processes or replacing chrome chemicals with vegetable tannins extracted from different parts of plants for leather industry [10, 20–23]. Application of vegetable tannin is considered to be cheap, ecofriendly, and sustainable and regarded as an alternative to chrome tanning [2, 24–26].

Varieties of vegetable tannins have been used around the world. Few vegetable tannins applied in different parts of the globe with variable concentrations are as follows: ashan bark 12%, chestnut 10.7%, gurjan bark 35%, quebracho 20%, Goran bark 26–36%, sumack leaves 25%, cutch 35%, avaram bark 18%, konam bark 11–14%, bambul bark 12%, myrobalam 30–40%, sandri bark 11%, dhundri bark 28–31%, kahra 16%, divi 35–45%, gorra bark, and behra nuts [27, 28]. The pods of *Acacia arabica* (Bagaruwa H) and wattle bark are also another source of vegetable tannins which are commonly used in Nigeria [29].

Such vegetable tannins are present in several plant species such as the bark of *Acacia mearnsii* and *Cassia singueana*, wood of *Schinopsis balansae*, bark of *Quercus* spp, and leaves of green tea and hamamelis plant species [30, 31]. Vegetable tannins can react with functional groups of collagen in hides and skins and form different bonds such as ionic, covalent, hydrogen bond, and weak hydrophobic interaction [25].

Cassia singueana plants (Figure 1) are short shrubs that grow to a height of 1.2 to 1.5 m with small yellow flowers which are widely found in different parts of Africa [32]. They are widely used as traditional medicinal applications to fight malaria and fever which are administered in different mechanisms [33, 34]. *Cassia singueana* leaf, stem, bark, and root extract possess antiulcer effect, stomach complaint and troubles, antioxidant effect, and fever reduction [35–38]. Toxicity study of *Cassia singueana* leaf extract on animals proved that the leaf extract is nontoxic [39, 40]. Furthermore, *Cassia singueana* bark extracted pigment was successfully used as dyeing crust for leather [29] and silk fabric [41] in the presence of natural mordant.

Therefore, the aim of this research is to extract vegetable tannin from *Cassia singueana* bark in comparison with the standards and apply on sheepskin as ecofriendly vegetable tannin to minimize the health and environmental impact of chrome tanning.

Figure 1: Picture of *Cassia singueana* plant.

2. Materials and Methods

2.1. Materials. Fresh bark of the *Cassia singueana* was collected from Tigray, Northern Ethiopia. One full-size wet salted sheepskin, chemical reagents, devices, and equipment are used from the Ethiopian Leather Industry Development Institute (LIDI), Addis Ababa, Ethiopia. The mimosa extracted tannin powder was obtained from Mimosa Extract Company.

2.2. Methods

2.2.1. Extraction of Tannins from Bark of Cassia singueana Plant. Matured barks of the *Cassia singueana* were randomly collected from the South and Southeastern zone of Tigray, Northern Ethiopia, from February to April 2021. The *Cassia singueana* barks were washed using distilled water and stockpiled in the refrigerator for a day. Then, the size of the barks was reduced using mechanical shredder and air dried at room temperature for seven days. The dried bark samples were ground using a grinder and sieved with 0.5 μm mesh size to obtain fine powder.

The extraction process of vegetable tannins from the bark of the *Cassia singueana* is illustrated in Figure 2. Vegetable tannin of the bark of *Cassia singueana* was extracted using an aqueous extraction method via an ecoinfrared dyeing machine. The powder was immersed in distilled water using varied combinations of powder concentration (40, 60, and 80 g/L), temperature (60, 80, and 100°C), and time (60, 90, and 120 min). The number of experimental trials (10 trials) and combinations of the parameters were conducted using statistical Minitab software. The resultant tannin solution obtained from each trial was subjected to cool and filtered solution using double-layered sateen polyester followed by Whatman No. 1 filter paper. The filtrate solution was exposed to a vacuum dryer at 60°C until

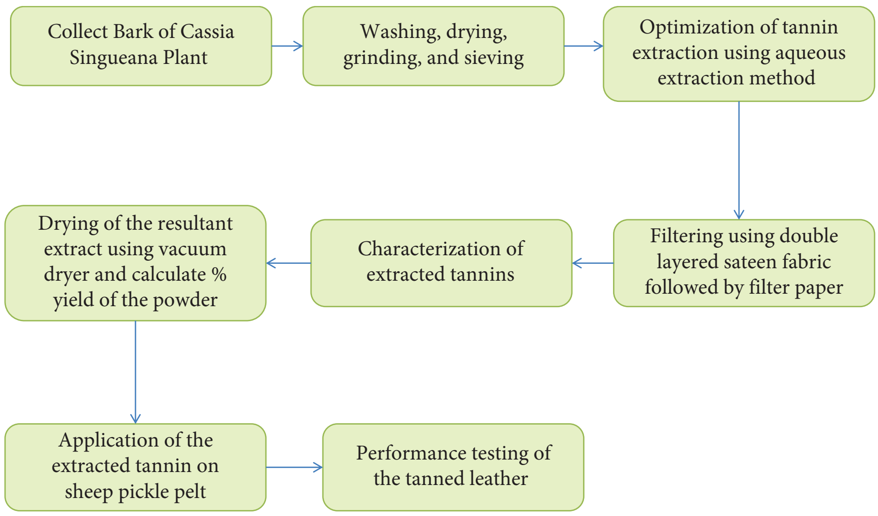

FIGURE 2: Scheme for extraction of vegetable tannins from *Cassia singueana* bark.

the solvent was completely evaporated. The percent yield of extract for each trial was calculated using the following equation:

$$\text{percent yield extract} = \frac{\text{resultant dried extract powder obtained (g)}}{\text{dried bark powder used as raw material (g)}} * 100. \quad (1)$$

Finally, a trial combination attaining the maximum % yield was taken as the optimum condition of tannin extraction from the bark of the *Cassia singueana* plant.

2.2.2. Characterization of Vegetable Tannins. Fourier transform infrared (FT-IR) spectroscopy (Perkin Elmer FT-112 Spectrum) was used to characterize the available functional groups in the tannin material. The FT-IR test was recorded in transmittance mode in the range of 4,000 cm^{-1} to 400 cm^{-1} wavelength.

2.2.3. Application of Tannins on Sheepskin. Fresh sheepskin was obtained from the Ethiopian Leather Industry Development Institute for the trial of *Cassia singueana* bark extract tannins. After identification of the optimum parameters for tannin extraction and the FT-IR analysis of the extracted tannins, the beam house operation was performed and the sheepskin pickle pelts were dissected into two equal portions. One portion was used for tanning with *Cassia singueana* extract and the other part was used for tanning with Mimosa vegetable tannin (standard) for comparison purpose at laboratory scale testing drum under the same conditions using conventional recipes as shown in Table 1.

2.2.4. Performance Evaluation of Tanned Leather

(1) Mechanical Strength of Tanned Leather Samples. Cassia singueana and Mimosa extract tanned leather samples were examined by mechanical features such as elongation at break, tear, and tensile strength. The test samples were prepared as per the International Union of Leather Technologists and Chemists Societies (IULTCS) method. The samples were conditioned under the standard temperature $20 \pm 2^{\circ}C$ and relative humidity $65 \pm 2\%$ for two days [42]. Elongation at break and tensile strength of tanned leather samples were measured according to IULTCS/IUP 6 in agreement with ISO 3376 : 2011. Similarly, tear strength was measured based on IULTCS/IUP 8 in agreement with the ISO 3377-2 : 2016 test method.

(2) Shrinkage Temperature of the Tanned Leather. The shrinkage temperature (Ts) of the tanned leather samples was measured according to the IULTCS/IUP 16 in agreement with ISO 3380 : 2015 test method to evaluate the thermal efficiency and hydrothermal stability of leather materials.

2.2.5. Chemical Constituents in Vegetable Tanned Leather. The chemical constituents like % of insoluble ash, total ash content, % hide substance, % moisture, degree of tannage, % oils and fats, and % water-soluble maters for both experimental and control leather samples were evaluated as per the standard procedures [43].

2.2.6. Spent Liquors after Vegetable Tanning. The amount of chemical oxygen demand (COD), biological oxygen demand (BOD), and total dissolved solids (TDS) of consumed liquor

Table 1: Recipe for tanning of sheep pickle pelt using *Cassia singueana* and Mimosa extract.

Type of process	Chemicals	Amount (%)	Duration (min)	Remark
Pickling	Water	50		Check °Be 6–8
	Common salt	7	15	
	Formic acid (1 : 10)	0.3	30	Check pH 3.5–4.0
	Sulphuric acid (1 : 20)	0.2	60	Check pH 3.5–4.0
	Drain 50% of the float			
Tanning	Mimosa (standard)	25	120	Check penetration
	Cassia singueana at 37°C	25	120	Check penetration
	Formic acid (1 : 10)	1	60	Check pH 3.8–4.2
Washing	Water at 35°C	100	30	Drain
	Water at 35°C	100	15	Drain
Fatliqouring	Fasfol Sc	2	60	Check exhaustion
	Lipsol J-622	1.5	60	Check exhaustion
Finishing	Leather was hanging on overhead track for overnight			

after leather tanning using *Cassia singueana* extract and Mimosa (standard tannin) were analyzed as per the standard procedures [44, 45].

3. Results and Discussion

3.1. Extraction of Tannins from Cassia singueana Bark. An aqueous method was used for the extraction of vegetable tannins from *Cassia singueana* bark. Different scholars reported that an aqueous extraction method is relatively economically feasible method [29, 46]. Distilled water was used as a solvent for the extraction of tannins at different combinations of bark powder concentration, extraction temperature, and time. The schematic diagram of the actual tannin extraction process is presented in Figure 3.

3.2. Optimization of Tannin Extraction

3.2.1. Percentage Yield of Extracted Tannin Solution. The percent yields of extracted tannins from different combinations of experimental trials are calculated using equation (1) which supports to optimize the extraction parameters. The higher % yield revealed that the trial combination contained the optimum tannin extraction conditions. The % yields of tannins from different combinations of experimental trials are presented in Table 2. A minimum of 9% tannin yield was recorded from trial two at a combination of concentration of 40 g/L, temperature of 60°C, and time of 60 min and a maximum of 36.83% tannin yield from trial five at a combination of concentration of 80 g/L, temperature of 100°C, and time of 120 min. Hence, concentration (80 g/L), extraction temperature (100°C), and extraction time (120 min) were selected as the optimum extraction conditions of tannins from *Cassia singueana* bark.

3.3. Effect of Extraction Parameters on % Yield of Tannins

3.3.1. Effect of Bark Powder Concentration on % Yield of Tannins. The effect of powder concentration on tannin % yield was examined by using different bark powder concentrations (20, 40, 60, 80, 100, and 120 g) at constant extraction time, temperature, and amount of solvent. It is clearly visualized in Figure 4 that the % yield increased sharply as the powder concentration was raised from 20 to 80 g. This is in agreement with mass transfer theory because the former presents a higher contact area between the solute and the solvent. Conversely, the % yield started to decrease abruptly while the powder concentration was still under incremental mode. Further increase in powder concentration restricted the free movement of particles, leading to reduction solubility and % yield of tannin extract.

3.3.2. Effect of Temperature and Time on % Yield of Tannins. To investigate the effect of temperature on % yield of tannins, different temperature ranges (40, 60, 80, 100, and 120°C) were examined at constant extraction time and powder concentration. The % yield of tannins showed a continuous increment from 8.1% to 32.12% with a subsequent increase in temperature from 40°C to 120°C (Figure 5(a)). The higher the temperature and agitation values, the higher kinetic movement of the particles achieved. This also supported to enhance the rate of mass transfer of materials from the surface of the solute to the bulk of the solution which could foster the rate of diffusion and solubility of the extracted substances. This in turn enhanced the % yield of the extracted tannins (~32.12%) [47].

To examine the effect of extraction time on % yield of tannins, different time intervals (30, 60, 90, 120, and 150 min) were considered. The duration of tannin extraction was arranged in an increasing trend while the other parameters such as temperature, sample size, agitation, and amount of solvent were kept constant. High % yield of tannin extract was achieved with an increased duration of extraction time. The contact time of the powder with a solvent increased from 30 min to 150 min and the % yield also increased from 6% to 21.5% (Figure 5(b)) which could be due to enhanced solubility/dissolution of the powder in the solvent.

3.4. Characterization of the Extracted Tannins. Cassia singueana extracted tannins were characterized by using physicochemical parameters and FT-IR spectroscopy.

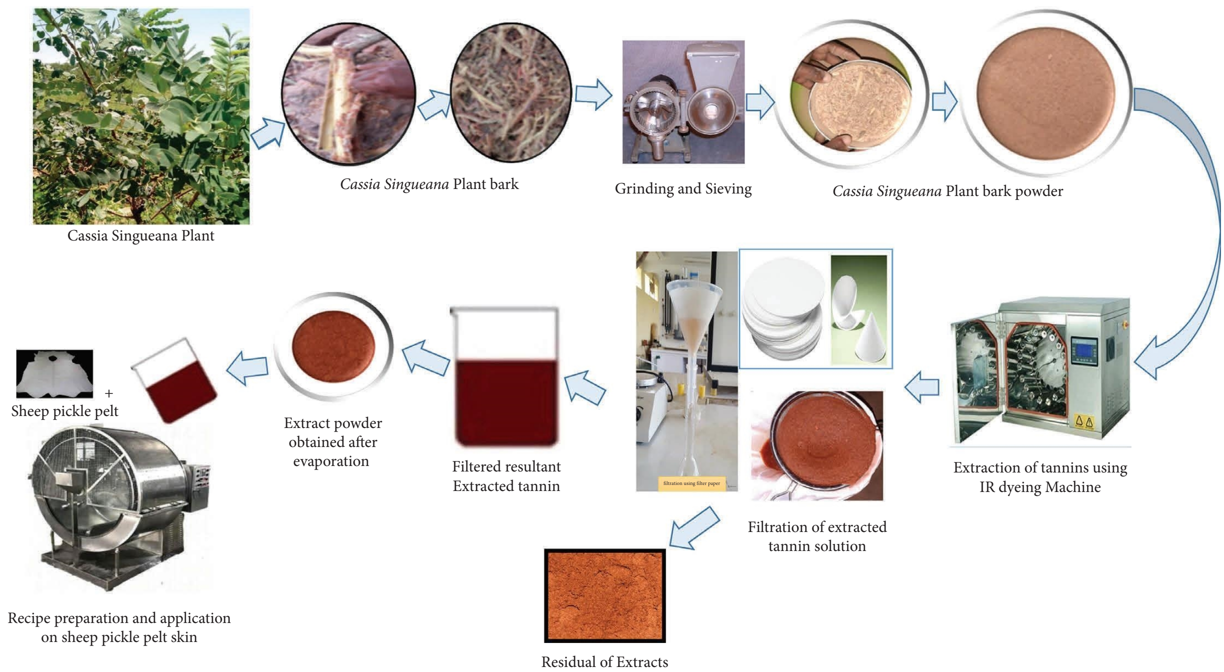

FIGURE 3: Schematic illustration of extraction of tannins from *Cassia singueana* bark.

TABLE 2: Percent yield of extracted tannins from *Cassia singueana* bark.

No. of trials	Bark powder concentration (g/L)	Extraction temperature (°C)	Extraction time (min)	Extract tannins (g)	Extracted yield (%)
Trial 1	60	80	90	15.54	27.56
Trial 2	40	60	60	3.6	9
Trial 3	80	60	60	10.25	12.81
Trial 4	80	100	60	19.25	24.06
Trial 5	80	100	120	29.46	36.83
Trial 6	80	60	120	16.88	21.1
Trial 7	40	60	90	5.73	14.32
Trial 8	40	100	120	12.8	32
Trial 9	40	100	60	8.2	20.5
Trial 10	60	60	120	9.15	15.25

The significance of bold in this table is just to indicate the trial attained maximum %yield of extract.

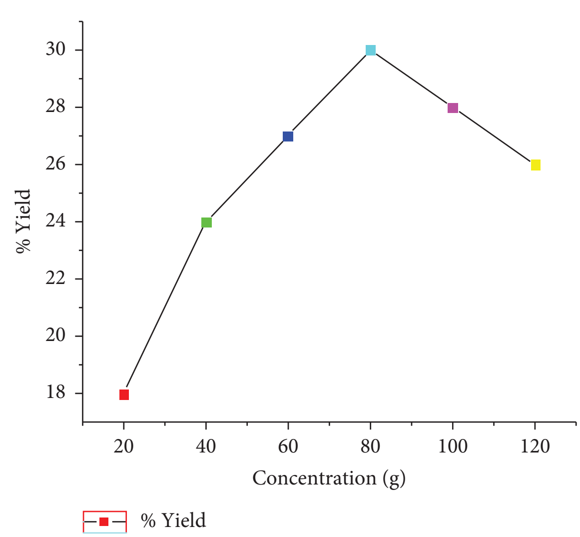

FIGURE 4: Effect of bark powder concentration on % yield of tannins.

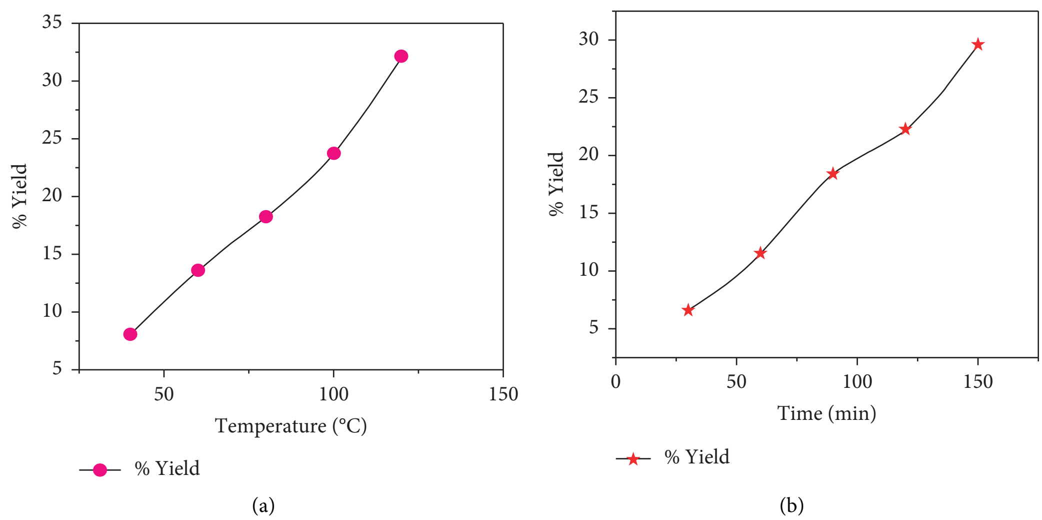

Figure 5: Effect of extraction (a) temperature, and (b) time on % yield of tannins.

3.4.1. Physicochemical Analysis. The physicochemical analysis (color and pH) of *Cassia singueana* bark extracted tannins and Mimosa standard is shown in Table 3. The pH level of the *Cassia singueana* bark extract is 5.16 and that of Mimosa is 5.3. The variation in pH is probably due to the method of extraction, type of solvent, and plant species. The color of the tannin is exactly the same, pink. The required pH range for effective leather tanning is in between 4 and 6 [48] which is in agreement with the findings of the present study.

Table 3: Physicochemical analysis of *Cassia singueana* bark and mimosa extracted tannins.

Items	*Cassia singueana* bark extract (experimental)	Mimosa (control)
pH	5.16	5.3
Color	Pink	Pink

3.4.2. Characterization Using FT-IR Spectroscopy. The FT-IR spectrum of *Cassia singueana* barks extracted tannin is shown in Figure 6. The most important peaks considered for the standard tannin in FT-IR analysis are 3423.03 cm^{-1}, 1520.87 cm^{-1}, 1062.12 cm^{-1}, 1620.02 cm^{-1}, and 1350 cm^{-1} [49]. A broad band at 3286.84 cm^{-1} shows the existence of the phenolic hydroxyl (-OH) groups attached to benzene ring. Another peak at 2922.28 cm^{-1} represents C-H and CH_2 stretching vibrations of aliphatic hydrocarbons. Particularly, specific peaks at 1153.48 cm^{-1}, 1101.4 cm^{-1}, and 1014.6 cm^{-1} showed the presence of carboxylic (C-O) groups attached to aromatic ring structures. Typically, the bands at 1650–1400 cm^{-1}, 1400–1100 cm^{-1}, and 1100–600 cm^{-1} belong to C=C, C-O, and C-H stretching vibrations of phenolic aromatic groups, respectively [50].

The FT-IR test results reveal that the vegetable tannins extracted from the bark of *Cassia singueana* plant are condensed tannins. In case of the condensed tannins, the monomers are interlinked through C-C or C-O-C bonds. Mostly, condensed tannins are known by their medical properties attributed to tannins [51]. The condensed tannins are also the major constituents in human nutrition, such as red wine, cocoa, chocolate, grape seeds, and others. These tannins are more richly found in different plant species with complex structure as compared to hydrolysable tannins [51].

3.5. Application of Tannins on Sheepskin. Pretanning of leather production was carried out based on the following conventional process: full-size sheepskin was treated with 50% of water and 7% of salt at 25°C for 15 min and then treated with 0.2% H_2SO_4 for 1 h in a drum rotating at 12 rpm. The skin was washed using tap water, and the pH was adjusted to 4.0 before treatment with vegetable tannin extract. Finally, the pickle pelt was bisected into two equal portions to test *Cassia singueana* extract and Mimosa (standard) extract experiment. Then, two batches of tannage process were arranged; tanning of the pickle pelt was performed using *Cassia singueana* bark extract and Mimosa tannin extract (standard) as control.

The weight of tannin extract was 25% of the pickle pelt's weight. The treatment was subjected to drumming for two hours at a temperature of 37°C and pH 3.9. Finally, the bath was neutralized to pH 4.2 to enhance resistance of the tanned skins to boiling water followed by washing and fatliqouring. Then, the leather was piled and dried. The dried leather was subjected to physical and chemical tests. The qualities of tanned leather samples are shown in Figure 7 which are evaluated according to the international standard methods.

3.6. Performance Testing

3.6.1. Mechanical Strength of Tanned Leather Sample. The results of % of elongation at break, tear strength, and tensile strength of tanned leather samples are shown in Table 4. The *Cassia singueana* extract tanned leather samples offered tensile strength of 15.6 N/mm^2, which is relatively better than the Mimosa (standard) tannin treated leather,

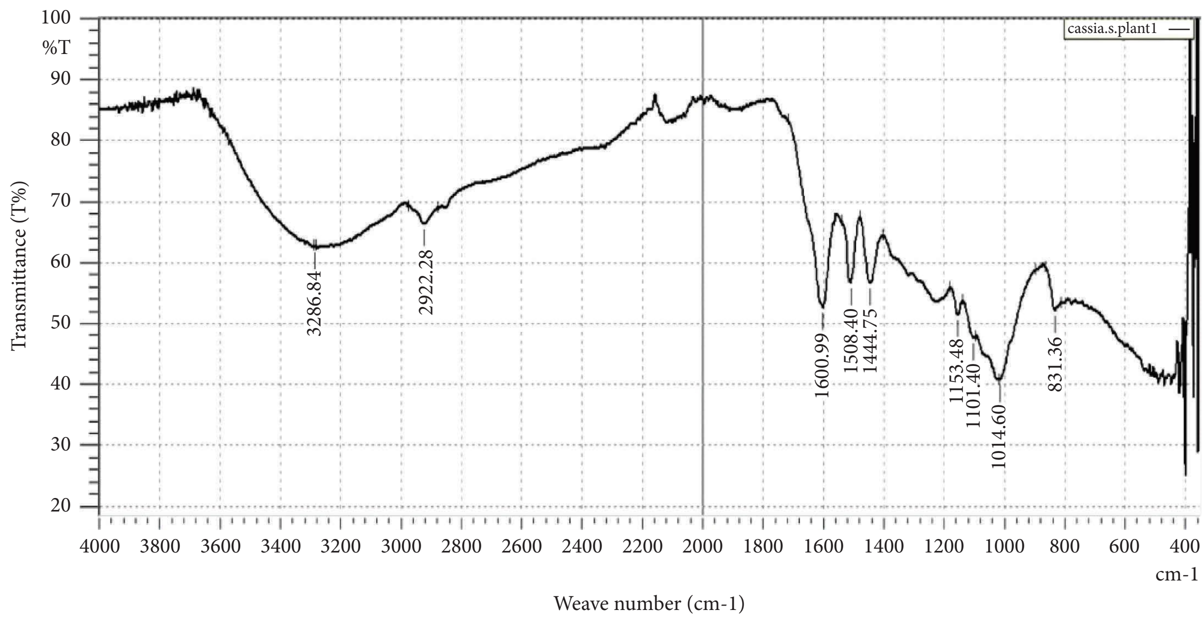

Figure 6: FT-IR spectrum of *Cassia singueana* bark extracted tannin.

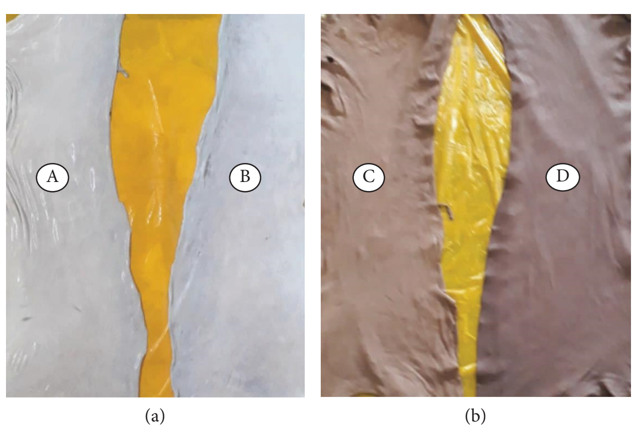

Figure 7: Sheep pickle pelt (A) control sample (pretanned), (B) before treatment, (C) treated with Mimosa bark standard, and (D) treated with *Cassia singueana* bark extract.

14.8 N/mm^2. This proved that the *Cassia singueana* extract possessed better tanning performance compared to that of the Mimosa tannin standard. Besides, quality of the hide collagen fibers influences tensile strength of the tanned leather.

The percent elongation of *Cassia singueana* extract and Mimosa (standard) tannin tanned leather samples recorded 45.3% and 38.7%, respectively. *Cassia singueana* extract tanned leather shows better percent elongation as compared to leather tanned with Mimosa standard tannin. According to IULTCS/IUP 6, quality leather should possess percent elongation greater than 40. Though the Mimosa tanned leather deviated a little, the percent elongation of *Cassia singueana* extract treated leather sample fulfilled the minimum values set by the IULTCS/IUP 6 standard.

Tear strength is the force used to initiate or continue a tear in leather under specified conditions. The tear strength of *Cassia singueana* extract and Mimosa standard tannin tanned leather samples recorded 24.2 N/mm and 22.5 N/mm, respectively. Both values are higher than the minimum allowed standard, that is, 20 N/mm set by the IULTCS/IUP 8. However, the result of tear strength for *Cassia singueana* extract tanned leather sample is slightly higher than that of the Mimosa standard extract tanned leather sample. Probably, *Cassia singueana* extract is rich enough with phenolic hydroxyl ($^-$OH) functional groups. Phenolic hydroxyl ($^-$OH) groups further create bond interaction and crosslinking with cationic amine (NH_3^+) groups of the leather collagen protein to form hydrogen bond and polyfunctional crosslinkings [42]. The mechanism tannin contains phenolic hydroxyl groups which can interact/crosslink with cationic amino groups of collagen protein by polyfunctional crosslinking to form hydrogen bonds [52, 53] to form nonputrescible and hydrothermally stable product called leather [54] (Figure 8). Moreover, there are physical hydrophobic interactions between the hexagonal structure of tannin and the protein structure which made the leather sable and resist external forces [55].

3.6.2. Hydrothermal Stability of Tanned Leather. Shrinkage temperature (Ts) is among the most important leather testing parameters which illustrate thermal stability of tanned leather collagen. Shrinkage temperature is the temperature at which leather starts shrinking in hot water [56]. Thermally stable leather withstands shrinkage even at high temperature. This is due to the formation of cross-links and a variety of strong bonds between the tannin components and the leather collagen. According to IULTCS/IUP 16, stating the shrinkage temperature of tanned leather should not be below 75°C [57, 58] confirmed that the leather samples tanned under this study are hydrothermally stable.

The shrinkage temperatures recorded for *Cassia singueana* extract and Mimosa (standard) tannins tanned

Table 4: Mechanical strength of *Cassia singueana* and Mimosa extract tanned leather samples.

Property	Tanned leather	
	Cassia singueana extract	Mimosa extract (standard)
Tensile strength (N/mm^2)	15.6	14.8
Elongation at break (%)	45.3	38.7
Tear strength (N/mm)	24.2	22.5

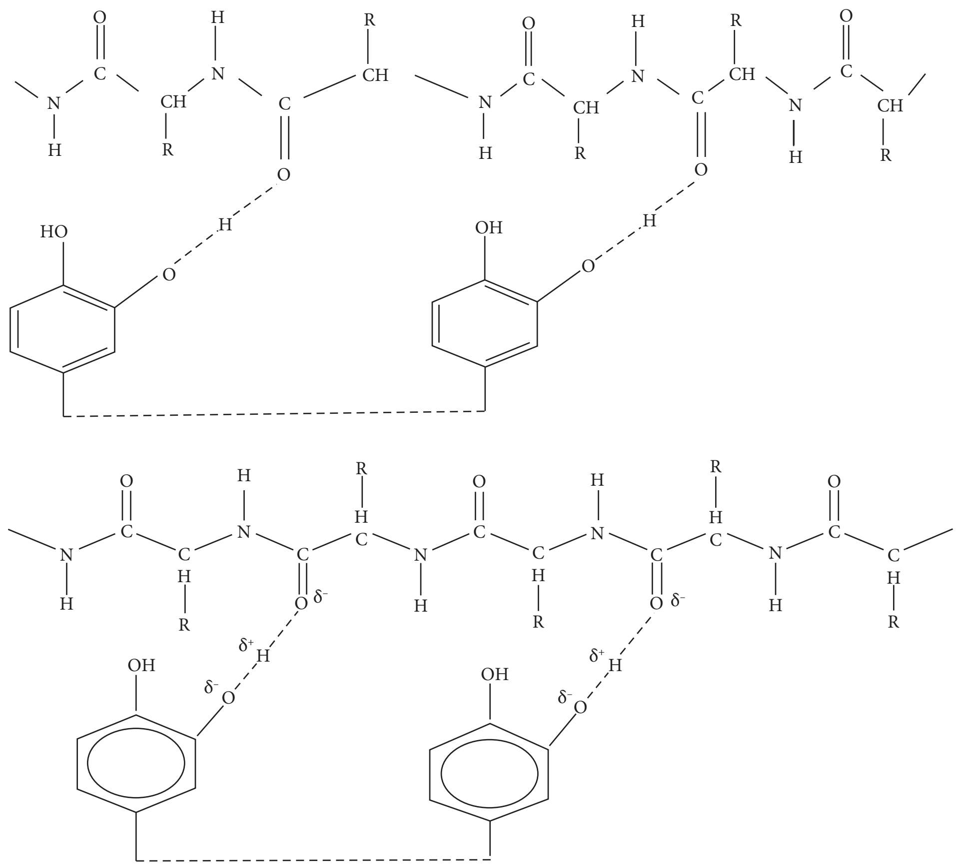

Figure 8: Typical interaction between vegetable tannins and collagen [6].

Table 5: Chemical constituents of *Cassia singueana* extract and mimosa extract tanned leather samples.

Parameters	Sample type	
	Cassia singueana bark extract tanned leather	Mimosa extract (standard) tanned leather
Moisture content	8.974 ± 0.071	9.017 ± 0.152
Ash content	3.255 ± 0.372	3.751 ± 0.064
Fat content	11.72 ± 0.8241	11.87 ± 0.4216
Hide substances (%)	50.3%	50.5%
Water-soluble matter	4.325 ± 1.221	4.461 ± 0.973
Degree of tanning (%)	56.5%	57.7%

leather samples are 83°C and 80°C, respectively. The reason for the higher shrinkage temperature of *Cassia singueana* extract tanned leather over the Mimosa extract tanned leather is probably due to the formation of excess cross-links/bonds between amine (NH_3^+) ions of the leather collagen and the hydroxyl (OH^-) ions of tannins (as shown in Figure 8) [57, 59].

3.7. Chemical Constituents Analysis of Tanned Leather Sample. The analysis of chemical constituents such as ash content, moisture content, fat content, hide substances, water-soluble matter, and degree of tanning was studied for tanned leather samples, and their results are shown in Table 5. The moisture contents of *Cassia singueana* extract and Mimosa (standard) tannins tanned leather samples were

Table 6: Pollution load generated from the liquor after leather tanning.

Parameters	Sample type	
	Cassia singueana bark extract	Mimosa extract (standard)
BOD	11760 ± 800	12420 ± 705
COD	33487.8 ± 325	346700.4 ± 460
TDS	18208.7 ± 700	22627.2 ± 800

recorded 8.974 and 9.017, respectively. Similarly, ash contents are 3.255 and 3.751, for *Cassia singueana* extract and Mimosa (standard) tannins tanned leather samples, respectively. Both the results of moisture and ash contents are within the acceptable range of leather production standards [60, 61]. All the chemical constituents of *Cassia singueana* extract tanned leather samples showed lower values compared to the Mimosa extract treated leather sample. Furthermore, the degree of tanning for both leather samples is in agreement with a minimum standard value of 50% [62].

3.7.1. Pollution Load for Spent Liquors after Tanning. The environmental impact (BOD, COD, and TDS) of the spent liquors after leather tanning with *Cassia singueana* extract and Mimosa extract (standard) was evaluated, and the results are illustrated in Table 6. A significant reduction of BOD, COD, and TDS results was observed for *Cassia singueana* extract tanned leather samples as compared to the Mimosa extract tanned leather samples. This might be due to the impacts of the soil type grown, type of fertilizers used during cultivation, and climate conditions. Vegetable tanning has significant importance in the reduction of pollution loads as compared to chemical tanning processes such as chrome tanning [63]. Therefore, the tannin material extracted from *Cassia singueana* bark could be suggested to be used as commercial tanning material in the leather manufacturing industries.

4. Conclusions

Vegetable tannin extracted from the bark of the Cassia singueana plant could be used as an alternative source of leather tanning replacing chrome tanning, an environmental friendly vegetable tannins replacing the use of chromium salts in the leather tanning industry. The plant is widely available in Ethiopia mainly in the northern part of the country, which makes the raw material cheap. Using this plant extract for the tanning of leather would give the benefits of reducing the import of synthetic tannins and minimizing environmental pollution. The efficiency of tanned leather with *Cassia singueana* bark extract was equivalent to those tanned with conventional Mimosa in all aspects of leather quality parameters and attained the results of all parameters more than the minimum set of standards. The result of pollution loads such as COD, BOD, and TDS reduction level of tanning liquors in experimental *Cassia singueana* bark extract tanning observed waste reduced as compared to the control Mimosa tanning. Additional advantages of the *Cassia singueana* plant over the Mimosa are its antimicrobial properties and medicinal applications, its ease of cultivation and growing, and its wide availability in Ethiopia and most of the African continent. In general, considering the environmental pollution aspect, the vegetable tannins extracted from the bark of the *Cassia singueana* plant can be used commercially as an alternative ecofriendly leather tanning. Moreover, another scientific research can be investigated on the possibility of using the residual extract/by-product of tannin extract as organic fertilizer.

Data Availability

All the data used in this study are provided in the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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