Sodom Apple (*Solanum Incanum*) Plant Material: A Greener Approach for Goat Skin Tanning Process

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Abstract

The use of natural materials that is eco-friendly on leather as vegetable tannins has become a matter of significant importance, as a result of increased environmental awareness to prevent some hazardous synthetic tannin. Therefore, this study investigated that the potential of the extracted tannin from Sodom apple (*Solanum Incanum*) fruit for its effectiveness as vegetable tanning agent on goatskins. It was extracted with distilled water, methanol, petroleum ether and ethanol by using Soxhlet extraction method. Although the amount of material extracted was significant in all extracting solvents, water was a more efficient solvent (extraction yield of 16.71%) than the others. The qualitative analysis and structural characterization of the extracts were done using thin layer chromatography (TLC), Ultraviolet (UV) spectrometer and Fourier Transformer Infrared (FT-IR) spectrometer. The analysis confirmed that the presence of condensed tannins in the extract, which usually used for the application of tanning process in leather manufacturing industry. On other hand, the Quantitative Analysis of Sodom apple fruit extract was conducted by evaluating its moisture content (7.59%), total soluble solids (21.45%), tannin content (12.13%) and non-tannin contents (9.32%). The Scanning Electron Microscope (SEM) was carried out to study the effect of the tannin system on the structural and morphological characteristics of the tanned leathers. Similarly, the organoleptic and strength properties of the tanned leathers were evaluated in comparison with the control ones. Finally, the pollution loads of tanning liquors in Sodom apple tanning significantly reduced as compared with the control (mimosa). Thus, the results in this study showed that the manufacture of leather based on Sodom apple fruit extract found to be a cleaner alternative and promising pathway for tanning goatskins.

1. Introduction

Tanning is a process in which the leather-making protein is completely stimulating against heat, enzymatic biodegradation, thermo mechanical stress by converting the fibrous protein of raw hide or skin into a stable material and making the leather to suitable for a wide variety of end applications [1]. In tanning processes tanning materials are able to crosslink with reactive site of fibrous protein, and it involves the conversion of putrefiable skin or hides to a non-putrefiable material by employing various techniques [2]. There are a wide variety of tanning agents that are available at the market. Some of the tanning agents that have been used currently include vegetable, alum, chrome, oil, aldehyde, and synthetic tannage.

Leather making is a lengthy process and involves the use of many different chemical and mechanical processes *viz.*, soaking, liming, deliming, pickling, tanning, post tanning and finishing. Among the processes, tanning is considered as one of the important processes that protect the leather against microbial degradation and tanning with vegetable materials is the oldest process in the leather sector. Although chrome tanning has gained importance in leather manufacture ad about 90% of leather is manufactured using chrome tanning systems, its advantage is over shadowed by its negative impact on the environment, which in turn because of the low uptake of Cr (III) salts which released in tannery

effluent. In general, leather making plant materials are the interest of tanners and a prominent theme for researchers in the area.

Vegetable tanning is the most eco-friendly method as compared to chemical tanning process and it discharge minimum pollutants to the environment. Vegetable tannins are polyphenols with molecular weight ranging 500 – 20,000 Daltons, which present in vegetable. The type, the maturity and the sources of vegetable tanning materials have an impact on the quality of leather regardless of tanning and post-tanning processes. Vegetable tanning uses vegetable materials (from leaves, fruits, seeds and arks) to process hides/skins into waterproof, non-putrefiable, soft and supple [1]. As a result, many researchers have been focused on the development of a greener leather tanning processes using new plant as a natural source materials (vegetable tannins). Vegetable tannins are plant-based polyphenols that are water-soluble and capable of reacting with collagen. Up to know, a very limited number of plant species are exploited for tanning applications. Recently attempts have been made to explore the use of new plant materials for tanning. Recently, in an attempt of the use of natural materials in tanning process, one of the co-authors in this manuscript have recently established the use of mekmeke (*Rumex abyssinicus*) for preservation, tanning and dyeing in leather manufacture [4–7]. Our extensive search indicates that researches is being undertaken to establish vegetable tanning using new plant materials. However, there is no reported literature indicated on the use of Sodom apple as a tanning agent. Thus, in this study, an attempt was made to evaluate the potential of Sodom apple for tanning with satisfactory hydrothermal stability and strength characteristics. Sodom apple (*Solanum incanum*) commonly known as bitter garden egg is one of the 1,500 *Solanum* species in the world that belongs to the family *Solanaceae*. It is a shrub, growing 1–3 m high with spines on the stem, leaves, stalks and calyces, and with velvet hairs on the leaves. The leaves are simple, ovate, elliptic, 2.5–12 cm long and 2.5–8 cm wide, alternate, flowers often borne in the leaf axilles, sometimes solitary or in few flowered clusters [8]. The fruits are small berries of 2–3 cm in diameter and yellowish orange or brown in color when ripe. It is also spherical, green, often striped with white, turning yellow to orange-brown when ripe [9]. It has different vernacular name in different ethnic language of Ethiopia for instance, “Embuay” in Amharic. This plant has been producing fruits twice a year and it is very easy to grow it especially in hot areas. Extracting the tannin from this plant and applying it for leather tanning process is economically and environmentally feasible and important.

2. Materials And Methods

2.1. Chemicals and Reagents

All chemicals and reagents used were of the required quality or grades unless otherwise explained. The extraction of tannin from Sodom apple, and proximate analysis were conducted at Arba Minch University chemistry laboratory. The characterizations of tannin, analyses of physico-mechanical characterization of tanned leather and its effectiveness and measurement of pollution load were conducted at Leather Industry development Institute (LIDI)-Addis Ababa, using the standard analytical methods for leather technology. During this work, the chemicals and reagents used were commercial grade chemicals and

auxiliaries for leather manufacturing process and analytical grade chemicals for the determination of pollution load parameters and other chemical analysis. The SLTC official white hide powder obtained from LIDI was used for gravimetric analysis to measure the tanning capacity of the Sodom apple materials. Wet salted goat skins of similar sizes were used in the tanning for experimental and control samples.

2.2. Collection and Preparation of Sodom Apple Fruits

A healthy fresh and matured Sodom Apple (*Solanum incanum*) fruit were collected from Arba Minch University, Arba Minch (Southern part of Ethiopia) using purposive random sampling method. The collected samples were washed with distilled water and stored in refrigerator. Then the fruits were cut into coarse pieces to reduce their sizes and kept in room temperature to dry it for a week. The dried fruits were grinded into fine powder using laboratory star mill and the powdered samples were stored in dry vacuum and the prepared powder was used as a raw material for extracting the crude tannins. For comparison purposes with the existing industrial practices, commercial extracts of wattle obtained from Mimosa Extract Company were used throughout the experiments.

2.3. The Optimization of tannin Extraction Procedure

A 20 gram of powdered Sodom apple fruit was taken and added into the extraction thimble while 200 mL of solvent placed in the flask of Soxhlet apparatus. Then the Soxhlet extraction processes were conducted for all solvents used for optimization and the extracted material was collected in collecting flask. The extraction was done by using methanol, methanol, petroleum ether, ethanol and aqueous solvent. All Experimental analysis were repeated three times for each set of plan that helped to determine as mean with standard deviation. The obtained extract for each solvent was filtered through Whatman No. 1 filter paper and the solvent was removed by rotary evaporation under reduced pressure at a temperature below 45 °C. The yield for each extract was determined based on the weight of the dried plant powder initially used. The results that gave high percentage yield were used for further study.

The selection of Sodom apple as a source of tanning agent was based on the preliminary test that was done in chemistry laboratory and the recommendation left by the people that were used in traditional way. After optimization of the extraction process it was identified that water was the best extraction solvent that gives best yield of tannin among solvents used and the vegetable bio-tannin was extracted from Sodom apple fruit powder by using water as a solvent. The prepared Sodom apple fruit dried powder a total of 1000 gram was exhaustively extracted using water as a solvent with powder-water ratio, 1:10 (W/V) by Soxhlet extraction method. The grounded fruit sample was added into the thimble and inserted into the soxhlet extractor tube and then distill water was placed into the round bottom flask after which the extractor was coupled. The temperature of the process was corresponded to the boiling point of solvent used and the extraction time was set for 12 hours. The extract was later concentrated into a thick paste using hotplate to dryness, then the dried extract was then crushed into powder using mortar and pestle then transferred to a pre-weighed vessel and the weight was determined.

2.4. Identification of Compounds by using Thin-Layer Chromatography (TLC)

Thin layer chromatography (TLC) technique is recommended to determine the number of components present in a mixture and to identify the compounds and to know its purity [10]. In current work for TLC technique, a combination of ethyl acetate, ethanol and distilled water (50:30:20) was used as solvent mixture to separate the components in the extracted material. A 0.5 mg of the extracted material was dissolved in extracting solvent and spotted on the surface of the TLC silica gel plate by using Thiele tube and placed into the chamber. The TLC plate was taken out while it reaches 75% on the top of the plate and the obtained color was circled. To detect the spots, the plate was taken and exposed to UV lamp and the spots were become visible. Finally the distance travelled by each component was recorded and the R_f value “retention factor” of the components were calculated

2.5. Preliminary Phytochemical screening of the extracts

A small portion of aqueous extract was dissolved in water used for the qualitative analysis and confirmation of the major phytochemical constituents' viz., flavonoids and tannins, according to different methods [10].

2.6. Determination of Tannins and non-Tannins

The quantitative analysis of tannins and non-tannins were analyzed using the gravimetric method which is based on the absorption of tannins by hide powder. For 6.25 g of dry hide powder, an equal volume of 3% chrome alum solution and 62.5 ml (10 times) of distilled water were added, stirred, and left overnight. The next day, the hide powder is transferred to a filter cloth and washed well with distilled water. After mixing and washing the chrome hide powder, the weight of the hide powder is taken and the same is adjusted to 26.5 g by the addition of distilled water. The determination of moisture content present in the selected powder was carried out using the standard method. From the extract solution, unfiltered extract was used for the determination of total solids, and the filtered extract was used for the determination of total soluble. The difference between the percentage of total soluble and percentage moisture, to determine the insoluble of the mekmeko extract. The chrome tanned hide powder was used for the determination of non-tannins. The tannin matter absorbed by the hide powder was determined by the difference between the percentage of total soluble and non-tannins.

2.7. Spectroscopic Studies of the Extracts

Fourier Transform Infrared Spectroscopy (FT-IR) studies were carried out for the experimental extract and the control commercial mimosa extract using FT-IR (Shimadzu IR Affinity 1, Japan). All spectra were recorded by absorption mode in the wave length range of 4,000 to 600 cm^{-1} wave numbers. Ultraviolet (UV) spectrums were recorded using Specord 50 PLUS-Germany UV-visible spectrometer.

2.8. Tanning Trials using the selected extract from Sodom apple

Goat, sheep and cow are the primary sources of skins used for leather manufacture. In this study, goatskins with average weight of 1 kg per skin were used for tanning on the basis of it is easy to handle, easily available, easy penetration of tanning agent and its durability [11]. Wet salted goat skins obtained from LIDI were used for the Sodom apple based tanning and the control Mimosa. Table 1.1 shows formulations of the tanning studies. After extracting and identifying tannin from Sodom apple fruit, the beamhouse operations was carried out until pickling process. After beamhouse operation taken place, vegetable tanning was employed in testing drum for both control and experimental pelts of the goatskins using normal recipes for vegetable tanning. In the present tanning experiments, each of the selected goatskins was cut into two halves. One piece was used for the experimental analysis which is Sodom apple fruit extract vegetable tanning and the corresponding half was used for the commercially used mimosa (control) vegetable tanning for comparison purpose. The detail tanning formulations for the experimental and control sample trials are depicted in Table 1.1.

Table 1.1
Recipe of Vegetable Tanning for Tanning the Experimental and Control of pickled Goatskins.

Pickling	Water		50%		Check °Be (7–8)
	Common salt		10%		
	Formic acid (1:10)		0.3%	30 min	
	Sulphric acid (1:20)		0.2%	60 min	
Tanning	Mimosa (control) done		25%	90 min	Check complete penetration
	in 3 portion		25%	2 hr	Check complete penetration
	Sodom apple (Experiment) in 3 portion		25%	90 min	
	Formic acid (1:10)		37 °C	1.0%	1 hr
Washing	Water	35°C	100%	30 min	
	Water		100%	15 min	Drain
Fatliquoring	Fosfol SC		2%	1 hr	Check Liquor exhaustion
	Liposo J-622		1.5%		
Finishing	Leather were horsed up overnight then dried by nailing				

2.9. Characterization of Tanned leather samples using SEM

In order to study the effect of vegetable tanning agent on the structural characteristics of the goatskin tanned leathers produced, the analysis of surface morphology of goatskin was carried out using scanning electron microscope (SEM). From the tanned goatskin, sample of 5 mm x 2 mm were cut from

the butt portion using fresh stainless steel blades after dehydration using aqueous alcohol. The samples were mounted both vertically and horizontally on aluminium stubs using an adhesive. These were then coated with gold using an Edwards E-306 sputter coater. The stubs were introduced into the specimen chamber of a FEI-Quanta 200 scanning electron microscope. The stubs mounted on the stage could be tilted, rotated and moved to the desired position and orientation. The scattered electron from the sample was then fed to the detector and then to a cathode ray tube through an amplifier, where the images are formed, which gives the information on the surface of the sample. The micrographs for the image were obtained by operating the microscope at higher voltage of 15 kV [12].

2.10. Physico –chemical Characterization of Tanned Leathers and Organoleptic properties

The properties *Viz.*, moisture content, oils and fats, hide substance, degree of tanning water soluble matter, and total ash content were determined based on the standard methods. The Sodom apple tanned crust leathers and control samples were assessed for tensile strength, percentage elongation at break and tear strength properties were measured as per IUP6 and IUP8 standard methods, respectively. The samples were also assessed for the functional properties such as softness, fullness, grain tightness, smoothness, and general appearance rated as on a scale of 0–10 points. The organoleptic properties of the samples were carried out by four experienced researchers and tanners from the leather processing division of Leather Industry Development Institute, Addis Ababa, Ethiopia.

Determination of the degree of shrinkage temperature

The temperature at which the leather started to shrink was noticed as the shrinkage temperature of the leather according to International Union of Leather Technologist 2001 and Chemist societies [13].

2.11 Measurement of pollution load generated from wastewater

The spent liquor from the experimental and control tanning process was collected and analyzed for pollution load parameters *viz.*, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Dissolved Solids (TDS) based on the standard analytical techniques.

3. Results And Discussions

3.1. Characterization of the extract as a tanning agent

The obtained yields of tannins were varied with the solvent types and time employed. From this the highest extraction yield was obtained when distilled water was used as a solvent than when other solvents used with a value of 16.71% in this study was achieved in 12 hours extraction time whereas the

lower percentage yield was found with 6 hours (11.11%).and the lowest yield was obtained with petroleum ether with value of 10.24%. In previous study [14] extracting of tanning materials from the bark using distilled water as solvent showed better yield that supports the current work results. It is concluded that extraction time and solvents are the main factors affecting the percentage yield of tannins and different solvents used for extraction of tannins were arranged as decreasing order of extraction efficiency which are Water, Methanol, Ethanol and Petroleum ether.

3.1.1. Phytochemical screening of sodom apple fruit extracts

The presence of tannins and flavonoids in powdered extract of Sodom apple fruit and mimosa (control) was confirmed using standard method of analysis BIS, [15] and the results were given in table.3.1.

Table 3.1
The phytochemical screening of extract materials in Sodom apple fruit.

Phytochemical		Test method	Color observed	Sodom apple	Mimosa (control)
Tannin		a) Ferric chloride	Green precipitate	+	+
		b) Lead acetate test	Yellow precipitate	+	+
Flavonoid		Ferric chloride	Dark – green	+	-
Tannin type	Hydrolysable	Potassium	No	-	-
	Condensed	hydroxide(aq)	Red precipitate	+	+
NB: + = present, – = absent					

3.1.2. Physico-chemical analysis of sodom apple fruit extract

The physico-chemical parameters like pH, moisture content, total solid, total soluble solid, tannin and non-tannin content of the extract were evaluated and characterized the obtained results were given in Table.3.2.

Table 3.2
Physico-chemical Analysis of Sodom apple fruit Extract.

Parameters	Sodom apple (<i>Solanum incanum</i>) fruit
pH	5.20
Moisture	7.59%
Total solid (TS) %	94.01%
Total soluble solid (TSS)%	21.45%
Non –tannin(NT) %	9.32%
Tannin (T)%= TSS-Non-tannin	12.13%

The current results given in table 2 are slightly different when compared with findings from other studies. The work done on Lawsonia Inermis (Henna) as vegetable tanning was reported that the amount of tannin obtained was 11.12%, non-tannin 22.64%, total soluble solid 33.76% and pH value 4.5 [16]. In other study [17] that conducted on the barks of *A. seyal*, *A. nilotica*, and *A. senegal* shown that the tannin contents were 12.15%, 10.47% and 3.49% respectively. These variations might be due to variations of solvent types and extraction methods employed, the environmental conditions, plant species, soil types, plant age and origin, water stress and the fruit or bark sizes used during the analysis. For any tanning material to be effective for tanning process the required range of pH is 4 to 6 [1], which is in a good agreement with the present study.

3.1.3. Thin layer chromatography

The TLC profile of the extracts was evaluated and the R_f values of each components were given in Table 3.3 and the results confirmed the presence of tannin in the extract.

Table 3.3
R_f values of Sodom Apple extract.

Plant specimen	Appearance (color)	Distance travelled by spots (cm)	Distance moved solvent (cm)	R _f values of the spots
Sodom apple fruit extract	Light brown	6.8	9	0.755
	Light blue	5.1	9	0.567
	yellow	2.9	9	0.322
	Blue	1.6	9	0.177

Clear inhibition zone were observed at R_f of 0.755, 0.567, 0.322 and 0.178. Among these points, 0.322 and 0,567 R_f values indicate the presences of tannins in the extract which is in good agreement with result of previous work done in [2]. The TLC visualized with UV lamp also contains different spots with different colors of light blue and blue, which may correspond to multiple classes of secondary metabolites.

3.1.4. Ultra violet-visible spectroscopy

UV-Vis spectroscopy was employed to identify the absorption maxima of the extracts within the wavelength range of 200 to 800 nm. To get the optimum absorption of the extract, different amounts of the sample were taken and analyzed using UV spectroscopy and the results were given in Fig. 3.3. The lower absorbance peaks might indicate the presence of non-tannin materials [18].

The optimum amount of extracted Sodom apple fruit that gives the maximum absorbance was the 1 g/100 ml of the sample which contains three inflection points at 258, 296 and 332 nm wavelength indicating the electronic transitions of π to π^* of benzene ring and that of carbonyls and none bonding electron to π^* energy levels respectively. The shift in the wavelength maximum absorbance of the extract was observed due to the difference in amounts of the extract especially in the case of 2 g/100 ml. Since the absorbance maxima of benzoic tannin is found in the range of 250 to 350 nm [19], the current absorbance maxima obtained was confirming the presence of tannin in the extract which is in the agreement with the mention wavelength range. The work done in [20] conveyed that condensed tannins were consistent the strong absorptions around 257 and 282 nm.

3.1.5. FTIR analysis

FT-IR was also conducted to study functional groups found in the extracted materials using the instrument with spectra range of $4000-400\text{ cm}^{-1}$ and the results were indicated in Fig. 3.4. According to FTIR analysis of standard tannin [21], the main peaks that are important to be considered will be 3423.03 cm^{-1} , 1620.02 cm^{-1} , 1520.87 cm^{-1} , 1350 cm^{-1} 1062.12 cm^{-1} .

The main bands that were important to specify the presence of Tannins in the extract are observed and indicated in the spectra that gives full information about the analyzed sample. The band above 3000 cm^{-1} and that found in the range of $1750\text{ to }700\text{ cm}^{-1}$ region are considered the most informative about tannin [22]. Based on the results obtained in this study, the IR spectral bands have confirmed that the extract of Sodom apple sample contains condensed tannin. This was proved through the absorption bands found at 1036 and 1400 cm^{-1} confirming the presence of asymmetric stretching of ester (C-O), band at 1598 cm^{-1} referred to stretching of C = C bonds of aromatic ring, weak band at 2927 cm^{-1} was indicating the stretching of C-H bonds of sp^3 or sp^2 (CH_3 or CH_2) hybridized carbon atom and bonds, and the strong broad band at 3274 cm^{-1} indicating the stretching vibration of O-H bond. These all information confirms the presence of condensed tannin in the extract.

3.2. Application of tannins on Goatskin

After the characterization and identification of tannin in the Sodom apple extract were conducted, application of tannin on the goatskin was followed. The application of the Sodom apple extract was done by comparing with the previously done tanning materials (mimosa) that was used as control. The tanning efficiencies of both control and experimental were evaluated and the tanned leather products

were shown in Fig. 3.5. All the tanning processes for both cases were operated under the same conditions (chemical percentages, temperature and drum speeds).

3.2.1. Scanning electron microscopy (SEM) analysis of the tanned leather samples

The scanning electron microscopic analysis provides information about the fiber compactness and the grain surface patterns of the leather [23]. In the current work, the grain images of the surface of the vegetable tanned leathers for both experimental and control were taken and presented in Fig. 3.6 with 15 kv magnification. It can be observed that the fibers of Sodom apple tanned leathers were found in the form of fine bundles whereas that of mimosa tanned leather appeared to have separated fiber bundles. This indicates that Sodom apple tanning has greater strength to associate with the goatskin than that of mimosa tanning material. Smooth grain surface is the indication of the interaction between vegetable tannins with collagen of skin modified grain surface without causing damage.

On the other hand, the distance between fiber bundles determines the number of pores in the leather. Thus, the numbers of appearance of porosities in Sodom apple tanned leather were higher than that of mimosa tanned leather. This shows that the Sodom apple extract is better than mimosa in the performance of tanning for good quality leather product. Vegetable tannins from different plant sources give different grain surface appearance, suggesting variations in molecular characteristics of the vegetable tannins [24].

Generally, the surface image of the crust clearly shows that the crust surfaces of the experimental leather has less number of hair pores, course surfaces and better fiber splitting and clean without any damage, whereas the control crust has more number of hair pores and fine surface.

3.3. Physical strength and organoleptic properties of the leathers

For good quality leather products, quality standards have been established. Thus, the vegetable tanned leather must be exposed to physical testing to evaluate their standard and qualities.

Tensile strength

The results of tensile strength for experimental tanned leather were showed an excellent strength as compared to control tanned leather as 14.2 and 12.5 N/mm² respectively. The extent of tensile strength depends on the quality of collagen fibers that the specific skin type contains. The increasing of tensile strength is due to the reactivity of tanning agents to the collagen fibers. The presence of – OH functional group in vegetable tanning agent favors the reaction with the functional groups in the collagen (C = O or NH₂) that can alter the properties of leather collagen. When vegetable tannins react with collagen, it improves the bonding between the fibers of the skin and stabilizes its structure [25]. Hence, Tensile

strength is the stress required to fracture a test specimen of specified thickness, fiber orientation and location on the skin.

Elongation at break (%)

Leathers with higher tensile strength have higher percentage elongation and vice versa. Good quality leathers should have a percentage elongation of greater 40% [26]. In this study the percentage elongation of Sodom apple tanned leather (experimental) was found to be 43.7% which is an excellent result as compared to mimosa tanned leather (control) which is 30.2%. Elongation of leathers is affected by pre-tanning, tanning and post tanning process which always differs from one tanner to another [27].

Leather thickness

The thickness of Sodom apple tanned leather and mimosa tanned leather were found to be comparable. Thickness of the leather greatly affects the stability of the skin by the formation of crosslinks between the tanning material and collagen fibers of the skin [26].

Tear strength

The minimum tearing strength should be at least 20N [26]. This study found the tearing strength of both Sodom apple and mimosa tanned leathers to be higher than 20 N which are 23.4 and 21.5 N/mm respectively. Tear strength indicated the maximum limit of the skin to be torn. The skin that was tanned with high levels tanning agents would have a high tear resistance.

Assessment of Organoleptic (Visualization) Properties of Crust Leathers

Leather inspections are not only done by Physico-mechanical tests but also through hands and visual evaluations for the aesthetic properties. Organoleptic properties, therefore, enables us to evaluate the leathers produced for various applications for their requirements by experienced industrial experts. Accordingly, the leathers were evaluated the properties viz., fullness, softness, grain tightness, smoothness, and general appearance rated as on a scale of 1–10 points with higher values indicate better property. This evaluation was carried out by three experienced researchers and tanners from leather processing technology of Leather Industry Development Institute, Addis Ababa, Ethiopia. As standard value, the higher level of the evaluation value should be above 5. The results of the current evaluations are given in Fig. 3.8, all of which are above the stated value for both experimental and control tanned leathers. All parameters evaluated were shown better values for experimental (Sodom apple) tanned leather than for that of control (mimosa) tanned leather.

3.4. Hydrothermal stability/shrinkage temperature of the leathers

Shrinkage temperature is a temperature at which leather starts shrinking in water or over a heating medium [27]. This is one of the most important parameters that characterizes the quality and stability of the leather. A high temperature value for shrinkage of leather is indicative of its hydrothermal stability due to formation of a large number of crosslinks by binding of tannins to collagen fibers present in the skin. The shrinkage temperature observed for Sodom apple tanned leathers and mimosa tanned leathers were found to be 75 ± 0.2 and 78 ± 0.3 °C, respectively as shown in Fig. 3.7. Good quality leather should have above 75 °C of shrinkage temperature as indicated in [28].

3.5. Proximate Analyses of the Vegetable Tanned Leather

The proximate analysis was conducted for both experimental and control tanned leathers and approximately all parameters analyzed were found to be comparable as shown in Fig. 3.9. The main purpose of determining moisture content, ash, fat, soluble matter and hide substance was to calculate the degree of tanning.

The moisture contents of Sodom Apple tanned leathers and mimosa were 9.038 ± 0.603 and 9.127 ± 0.514 respectively. The relative humidity of an area is a determinant factor in the moisture content of all leathers. Low moisture content affects the tensile strength, flexing endurance and ball burst test of the leathers. But the moisture content of all leathers falls within the range for production of leathers [29].

The Ash contents of the experimental and control tanned leathers were found to be 2.874 ± 0.268 and 3.935 ± 0.095 respectively that were determined by using the furnace incineration method. These results were in agreement with earlier reported works [29, 30]. The Fat content of the crust leather of experimental was 11.02 ± 0.6142 as compared to control 11.54 ± 0.2412 , in which the experimental shows relatively less fat content than the control one. High levels of oil/fat in the leather can cause discomfort to the wearer and it may also facilitate it undergo oxidative reaction that may lead to rancidity (decay) [29]. The result affirmed that Sodom apple tanned leather better as compared to mimosa tanned one.

Total soluble matter corresponds to the fixation of tannins on the collagen and makes the stabilization of leather. The results of the current work show that water soluble matters of experimental and control tanned leathers were 4.1516 ± 0.9977 and 4.553 ± 1.232 respectively. The hide substance of Sodom Apple and mimosa tanned leathers were 49.2% and 50.8% respectively, which is similar to the values in previously work done [31]. And the tanning degree values of experimental and control tanned leathers were 54.2% and 57.4% respectively, which both values show good agreement with standard minimum value of 50% [12].

3.6. Evaluation of Pollution Loads Generated in tanning Liquors

The pollution loads of the vegetable tanning processes for both experimental (Sodom apple) and control (mimosa) tanned leathers were evaluated in terms of BOD, COD and TDS after collecting the liquors of tanning effluents and the results are presented in Table 3.4. There is a difference between the experimental and control leather tanning processes. If it was compared with the chemical tanning processes, it would be significantly different showing the importance of vegetable tanning for the reduction of pollution load in environment, especially in reduction of chromium effect on the environment.

Table 3.4
Pollution generated in the tanning liquors of mimosa and Sodom apple tanning.

Parameters	Type of sample	
	Mimosa (Control) tanning	Sodom apple (Experimental) tanning
BOD ₅	13560 ± 700	12250 ± 803
COD	35000.6 ± 400	33567.5 ± 250
TDS	29406.0 ± 1000	16105.0 ± 900

The cleaner production options using natural products as vegetable tanning materials during leather processing to reduce BOD, COD and TDS was recommended in the work [32]. Therefore, the Sodom apple tanning leather process was proved and recommended to be employed commercially and used worldwide in tanning leathers. Furthermore, the results of the pollution load obtained in the current work are in good agreement with the results in [33], the work done on the leather tanning process using Sunt bark.

4. Conclusions

In the present work, the extracts of Sodom apple were observed to be a good alternative for use as tanning agent in leather manufacture. By using a minimum of 20% Sodom apple extract, it is possible to obtain a shrinkage temperature of 75°C. The leather characteristics including the tensile and tear strength for Sodom apple extract were observed to be promising results for leather manufacture and it is on par with that of the control samples. Most organoleptic properties of the experimental leathers produced from Sodom apple (*Solanum Incanum*) fruit extract and mimosa were also compared and found to be better in experimental leather than control leather that produced from mimosa. The study was also conducted on the pollution loads of tanning liquors in both Sodom apple tanning and the mimosa to evaluate reduction levels of COD, BOD and TDS released along the wastewater during tanning and it was found that the waste reduction was seen in the Sodom apple (experimental) tanning than the mimosa (control) tanning. In general as a conclusion, it is revealed that the quality of leather tanned with Sodom apple tanning material was better in almost all aspects of leather quality parameters as compared with that of the mimosa (commercially available) tannin and can be considered as a greener alternative for tanning process in leather manufacture.

Declarations

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Authors contribution

The author(s) read and approve the final manuscript

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Availability of data and materials

The authors declare that the manuscript contains the minimal dataset that is required to interpret, replicate, and build upon the methods and findings reported in the article. Raw data can be shared via correspondence upon reasonable request.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that we have no competing interests

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Figures

Figure 1

UV-Vis absorption spectra of Sodom Apple extracted tannins

Figure 2

FTIR Spectrum of extracted Tannins.

Figure 3

Photos (A) Leather tanned with Sodom Apple and (B) Leather tanned with mimosa.

Figure 4

Scanning electron micrograph of (a) experimental (Sodom apple fruit) and (b) control (mimosa) vegetable tanned leathers.

Figure 5

Scanning electron micrograph of (a) experimental (Sodom apple fruit) and (b) control (mimosa) vegetable tanned leathers.

Figure 6

Proximate analyses of both experimental and control vegetable tanned leather.