Extract of *Trema Orientalis (L.)* Stem Bark: A Potential Source of Environmentally Friendly Tanning Agent for Leather Industry

by

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Abstract

Researchers around the world are in continuous endeavor to develop environment friendly tanning agent due to adverse effect of conventionally used chromium during leather tanning. Recent trend of tanning is thus heading to chrome-free and greener chemical processing options. Vegetable tanning is an exoteric leather processing technique because of their lower pollution load on the environment. Considering the inadequacy and high costing for the commercialized tannins, development of alternative tannins from locally available plants and their characterizations are important. In this research, the stem barks of *Trema Orientalis (L.)* were extracted at different temperatures employing water solvent with or without additives (sodium hydroxide or sodium sulphite) to attain phenolic-rich extractives. To ascertain appropriateness as a vegetable tanning agent, the obtained extracts were thereafter characterized in respect to yield, total phenolic content, tannin content and molecular structure. The extraction yield for all extracts improves and the quality remains nearly unchanged with temperature rising. The elevated concentration of chemical additives enhances the extraction yield but lessens the quality of extracts. In terms of extraction yield and the quality of extracts the best condition for extraction was discerned at 80°C with water solvent. This water extract has a decent extent of phenolic and tannin content of 266.13 mg Gallic acid equivalent/ gm of dry extract and 30.12% respectively. The final extract exhibits excellent leather retanning tendency comparable to the commercial *quebracho* tannins.

Introduction

In leather industry, tanning is the chemical process where the putrescible animal hides and skins are converted to leather.[1] Through tanning process the raw hides or skins are converted to a durable material and ready for wide range of end applications.[2] During tanning, tanning agents directly link to the leather through the functional group of collagen and exhibit physical & chemical resistance.[3] The common tanning techniques are mineral tanning, chrome tanning, aluminum tanning, aldehyde tanning, vegetable tanning, oil tanning, combination tanning, etc.[4] Different characteristics are obtained from different tanning methods.[5] Amongst these, chrome tanning is globally most popular technique for leather tanning where chromium (III) salts are employed.[6] About 85% of all leathers produced globally are according to the chromium tanning method.[7] Chrome tanning, a 100 years old tanning technique, is one of the greatest inventions in the history of leather making.[8] Although chrome tanning has been proven as an excellent tanning technology; lack of proper handling might lead to possible risk associated in term of toxicity relating to hexavalent chromium.[9] It is crucial to assure 100% safety for people connected in leather production, for the environment and for the leather product end user in order to be compliant with today's sustainability standards. Vegetable tanning techniques are current trends in tanning for sustainability of the leather industry.[10]

Vegetable tanning processes are performed employing natural vegetable tannins which are available in powder or liquid form and are obtained from leaves, bark, roots, fruits, seeds or galls of plants.[11,12] Tannins are polyphenolic compounds with molecular weight ranges of 500 to 20,000 Da, soluble in water and capable of forming reversible and irreversible complexes with proteins, polysaccharides, alkaloids, nucleic acid & minerals.[13] The greater affinity of tannins for proteins is assigned by the number of phenolic groups in tannins since at the peptide bond in protein this is the binding position to carboxyl carbon.[14] Based on to the chemical structure tannins are classified into hydrolysable and condensed tannins.[15] Hydrolysable tannins carry a polyhydric alcohol in center, for example glucose and hydroxyl groups which is partially or fully esterified with gallic acid (gallotannins) or hexahydroxydiphenic acid (ellagitannins).[16] Condensed tannins are oligomers or the non-branched polymers of flavonoid units.[11,17] In leather tanning, the interaction mechanism between vegetable tannins and collagen of skin differs depending on such classes of tannins because of their distinct structures.[18] Both hydrolysable and condensed tannins are capable of forming powerful complexes with certain types of protein though they are structurally different. Condensed tannins are more preferred than hydrolysable tannins but their combination produces excellent leathers.[13]

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Most of the plant species in the world provide tannins but only a few of them contain acceptable extents necessary for commercial interest of leather tanning.[6] Mimosa, quebracho, chestnut extracts etc. are commercial tannins used for leather tanning and retanning technology.[3] Because of the insufficiency and high price involved for the commercially available tannins; the use of these tannins is limited for the cottage tanners.[19] So, the development of alternative tannins from indigenous plants and their characterization is crucial.

T. Orientalis (L.), locally known as Nalita, is a shrub and rapid growing tree belonging to the Family of Ulmaceae.[20,21] It is widespread in Bangladesh as well as many other countries like India, China, Nepal, Myanmar, Japan, Philippines, Indonesia, Malaysia, Saudi Arabia, Ghana, Senegal, Cote d'Ivoire, Australia, Brunei, Kenya, Sudan, Tanzania, Uganda, Vietnam, Zimbabwe etc.[21,22] It is widely used for medicinal purposes such as remedy of coughs, sore throats, asthma, bronchitis, gonorrhea, yellow fever, toothache and dysentery.[23] In addition to that it is also used in paper making.[24] Literature shows that *T. Orientalis (L.)* plant consists of rich amount of phenolic compounds.[21,25–28] Despite containing satisfactory amount of phenolic compounds still no research has been executed for selecting the appropriateness of *T. Orientalis (L.)* as vegetable tannin source for applying in leather industry. The objective of the present work was to assess the prospect of *T. Orientalis (L.)* stem bark's extract as an alternative to conventional vegetable tanning or retanning agents.

Experimental

Materials

T. Orientalis (L.) stem bark was collected from the garden of Pulp and Paper Research Division, BCSIR Laboratories Dhaka, Bangladesh Council of Scientific and Industrial Research. Then it was air dried and milled to powder using an analytical grinder. Hide powder was obtained from Chemical Research Division. The gallic acid was certified reference material (CRM) grade and other chemicals were analytical grade. The chromed tanned leather was obtained from leather processing division.

Extraction Process and yield of extract Calculation

For each extraction process 20 gm powdered bark was immersed in a glass beaker containing 400 ml distilled water which was then placed in a water bath. The beaker was covered with aluminum foil to prevent water evaporation. The processes were conducted at 50° and 80°C except stirring for 4 h either by water only or subsequently adding sodium hydroxide (0.5 and 1.0% of dry bark weight) or sodium sulphite (2.0% of dry bark weight). Then the extracts were filtered through vacuum filter and the filtrates were concentrated by a rotary evaporator at 60°C and finally freeze dried.

The Yield of extract was calculated as:

Yield (%): (Weight of oven dried extracts in grams/ Weight of the oven dried *T. Orientalis (L.)* bark in grams) × 100

Total phenolic content determination

Total Phenolic Content were measured by the Folin-Ciocalteu method[29] according to the literature.[30] For calibration curve the gallic acid was used as standard and the results were expressed as the total phenolic content in milligram of gallic acid equivalent (GAE) per gram of dry extract.

Determination of tannin content

Tannin content was quantified by hide-powder method (SLC117) as stated in literature [13] and is described as the extent of soluble solids of tannin extract is being absorbed by standard hide powder. So, the tannin content (%) was calculated from the difference between the total soluble solids (%) and the soluble non tannins (%).

Identification of tannin class by FT-IR spectroscopic method

The molecular structure of extracts/tannin was studied by Perkin Elmer FT-IR Spectrophotometer (Frontier) equipped with an ATR unit at a resolution of 4 $cm^{-1}$with 32 scans in the frequency ranges of 4000–600 cm^{-1}.

Retanning process of leather

The retanning processes of conventionally processed wet blue goat skins (chromed tanned leather) were executed by applying *T. Orientalis* stem bark extract (extract obtained at 80°C with water solvent) as experimental trial and commercial *quebracho* tannin as control trial. In both trials 8% tannin (based on dried weight of wet-blue material) and 1% syntan were used.

Characteristics of retanned leather

The retanned leather of experimental and controlled trials were finally characterized in terms of tear strength, tensile strength and percent elongation at break according to the SATRA TM 162, TM 43 and TM 43 respectively.

Results and Discussion

Extraction yield

The extraction processes were conducted at 50° and 80°C temperature employing water with or without additives (NaOH or Na_2SO_3). Water was chosen as solvent in this study by reason of on industrial scale other solvents were regarded problematical especially with respect to pollution, recycling and cost.[31] Table I exhibits the results of extraction yield and other characteristics of *T. Orientalis (L.)* stem bark extracts at different extraction conditions along with the properties of commercially used tannin *quebracho*.

Table I

Extraction yield and characteristics of *T. Orientalis* stem bark extracts and *quebracho* tannin

Extracts/Tannins	Solvent	Additives	Temperature (°C)	Yield (%)	Total Phenolic Content (mg GAE*/dry extract)	Tannin Content (%)
Quebracho	Unknown	-	-	-	510	57.56
T. Orientalis (L.)	Water	-	50	7.24	264.45	30.12
	Water	-	80	12.14	266.13	30. 36
	Water	Na_2SO_3 (1 %)	50	8.21	257.41	15.78
	Water	Na_2SO_3 (1 %)	80	13.18	257.19	14.98
	Water	Na_2SO_3 (2 %)	50	11.34	258.56	13.25
	Water	Na_2SO_3 (2 %)	80	17.31	258.61	12.68
	Water	NaOH (0.5 %)	50	25.80	60.46	<5
	Water	NaOH (0.5 %)	80	37.39	49.09	<5
	Water	NaOH (1.0 %)	50	33.60	49.33	<5
	Water	NaOH (1.0 %)	80	46.30	32.41	<5

*GAE-Gallic Acid Equivalent

Depending on the extraction condition the extraction yield of *T. Orientalis (L.)* stem bark extracts were ranges from 7.24-46.30% (Table I). The highest yield (46.30%) was attained for extraction with water plus 1.0% NaOH at 80°C temperature. The extraction yield of all extracts were increased with temperature rising (Figure 1) due to the improvement of compound solubility at higher temperatures as well as may be because of the enhancement of mass transfer to the liquid from the matrix of bark.[3] The yield of extractions were remarkably enhanced with increment of alkalinity of NaOH (Figure 2) as a result of rising solubility of lignin in NaOH solution[32] and considerable quantity of lignin were previously identified in *T. Orientalis (L.)* plant.[20,24,33,34]

Characterization of extract

Though the yield of the extraction indicates the performance of extraction, the suitability of extracts for leather tanning or retanning process relies on its characteristics such as total phenolic content, tannin content, types of tannin, etc.

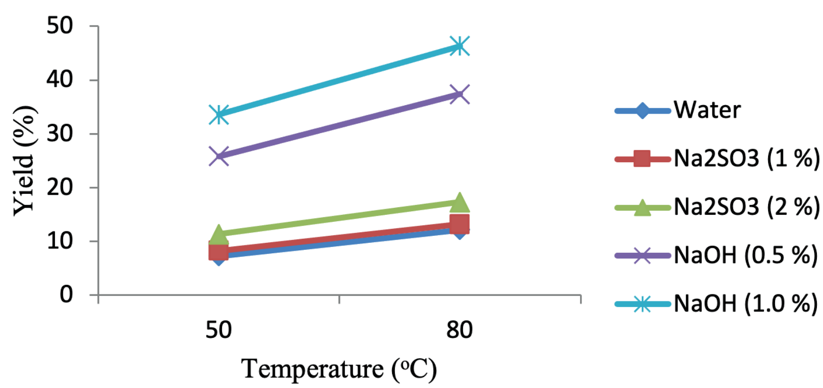

Figure 1. Effect of temperature on extraction yield of *T. Orientalis (L.)* stem bark extracts in water and alkaline solution.

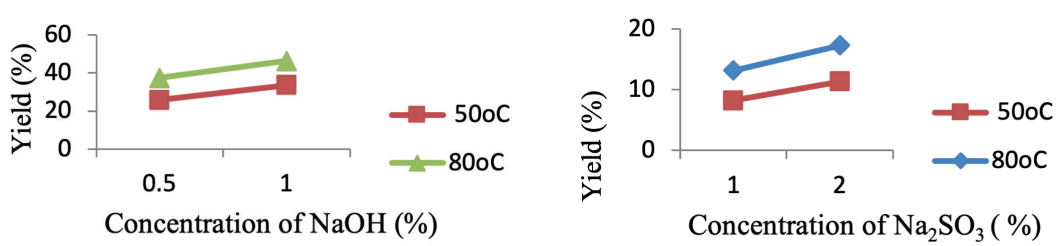

Figure 2. Effect of alkalinity on extraction yield of *T. Orientalis (L.)* stem bark extracts at different extraction temperature.

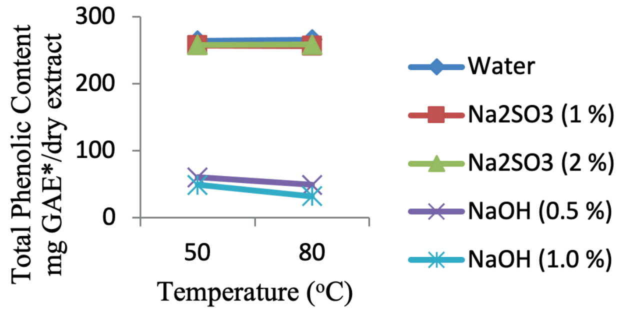

Figure 3. Effect of temperature on Total Phenolic Content of *T. Orientalis (L.)* stem bark extracts in water and different alkaline medium. *GAE-Gallic Acid Equivalent

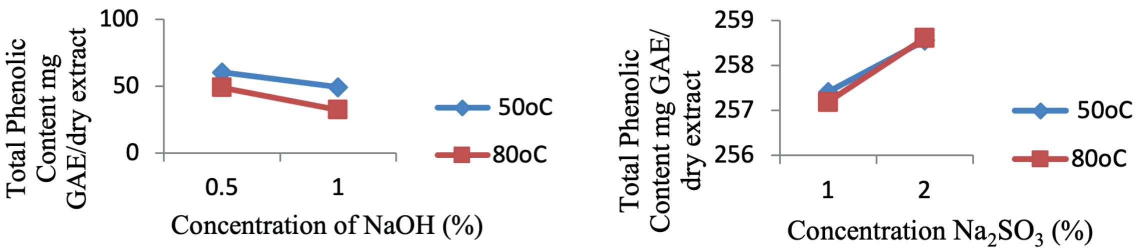

Figure 4. Effect of alkalinity on Total Phenolic Content of *T. Orientalis (L.)* stem bark extracts at different extraction temperature.

Total phenolic content and tannin content

Water extracts of *T. Orientalis (L.)* bark exhibits, for all extraction temperatures essayed, remarkably higher total phenolic content than alkaline extracts (exception for sulphited extracts). The influence of temperature on total phenolic content at different extraction medium was not significant (Figure 3). Greater alkalinity of NaOH reduced the phenolic contents remarkably (Figure 4), these happened since the alkali improved the solubility of non-phenolic compounds such as lignin in the course of extraction processes, as earlier discussed. The maximum value of total phenolic content (266.13 mg GAE/gm of dry extract) was found for the extraction with water at 80°C temperature and minimum value (32.41 mg GAE/gm of dry extract) was for the extraction with water plus 1.0 % alkali at 80°C temperature (Table I). A research performed in Ivory Coast showed that water extract of *T. Orientalis (L.)* bark had a total phenolic content of 240.73 mg GAE/gm of dry extract,[35] which is almost similar to the data found in our analysis.

Similar to the phenolic content of *T. Orientalis (L.)* bark extracts, extraction temperature did not show pronounced effect on tannin content (Figure 5). Higher alkalinity of Na_2SO_3 slightly reduced the amount of tannin content (Figure 6). The highest value of tannin content (30.36%) was observed for extraction with water at 80°C temperature (Table I) and the lowest value (not shown in table) was achieved for extraction with water plus 1.0% NaOH at 80°C.

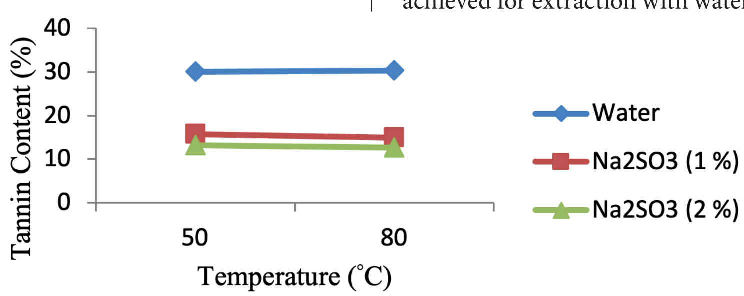

Figure 5. Effect of temperature on Tannin Content of water and sulphited extracts T. Orientalis (L.) stem bark.

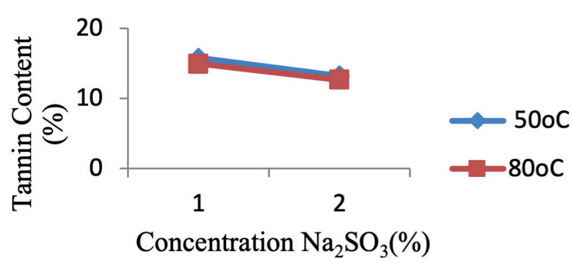

Figure 6. Effect of concentration of Na_2SO_3 on Tannin Content of extracts of *T. Orientalis (L.)* stem bark at different extraction temperatures.

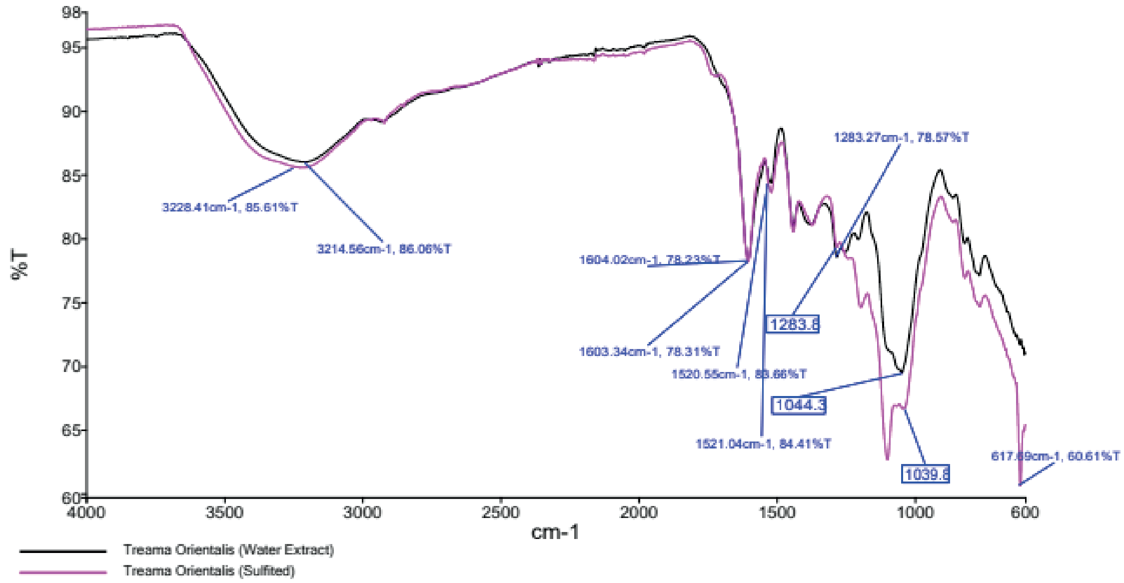

Figure 7. FT-IR spectra of water and sulphited extract of *T. Orientalis (L.)*

FT-IR Analysis

According to their molecular structure tannins are classified into hydrolysable and condensed tannins. In leather tanning condensed tannins are more preferred than hydrolysable tannins. FT-IR spectrum was used for identifying the molecular structure of water and sulphited extract of *T. Orientalis (L.)* stem bark (Figure 7). Commercial *Quebracho* tannin was used as control. NaOH extract was not considered in this analysis because of its lower tannin content.

Hydrolysable tannins exhibit spectrums band in the region of 1722–1702 cm^{-1} for the C=O stretching of esters, basically gallic acid derivatives.[36] These types of tannins also represent spectra at 1325–1317 and 872–870 cm^{-1} for symmetric stretching of C-O bond of ester and the presence of gallotannins (subclasses of hydrolysable tannins) respectively.[37] For *T. Orientalis (L.)* extracts and selected commercial tannins no peak was observed in these areas. Condensed tannins show medium to strong peaks of C=C–C stretching between the region of 1555–1503 cm^{-1}.[36] The spectrums of 1288-1283cm^{-1} are the indication of flavonoid-based condensed tannin, which is allocated to the ethereal C-O asymmetric stretching vibration from pyran-derived ring structure.[37] The sharp bands near 1520 cm^{-1} and 1283 cm^{-1} for both water and sulphited extracts indicates the existance of condensed tannin in *T. Orientalis (L.)*. The commercially known condensed tannin *Quebracho* also shows spectrum in these regions (spectrum not shown). The spectrum in the region of 680-600 cm^{-1} is attributed for the C-S vibration of sulfonic groups.[31] Reasonably, water extract does not expose any peak in this region and suphited extract represents this peak at 617 cm^{-1}. Though the extraction method is unknown, the absorption band in the 680-600 cm^{-1} area represents the possibility of sulfitation extraction method for *Quebracho* tannin.

Characterization of retanned leather

The properties of leathers retanned with *T. Orientalis (L.)* extract and commercial *Quebracho* tannin is given in Table II. The test results of tear strength, tensile strength and % elongation at break of leather retanned using *T. Orientalis (L.)* extract were comparable with leather retanned with commercial *Quebracho* tannin.

Table II

Characterization of retanned leather

Retanned leather	Tear strength (N/mm)	Tensile strength (N/mm^2)	Elongation at break (%)
Experimental trial	30.6±0.4	15.26±0.2	34.8±0.5
Controlled trial	31.15±0.3	15.60±0.4	36.2±0.7

± sign indicates the standard deviation of the measured values

Conclusions

The current work was done to utilize the stem bark extracts of the locally available *Trema Orientalis (L.)* plant as a leather retanning agent. The results of extraction yield, total phenolic content, tannin content and molecular structure of the all *T. Orientalis (L.)* stem bark extracts prove that extraction with water at 80°C provides the best quality extract. The final retanned leather exhibits excellent properties comparable with leather retanned by commercial *Quebracho* tannin. This research gives fruitful results for potential utilization of *T. Orientalis (L.)* plant as tannin source for increasing the supply of tannin towards improvement leather sector in Bangladesh and other countries.

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