THE *Journal* OF THE AMERICAN LEATHER CHEMISTS ASSOCIATION

November 2023 Vol. CXVIII, No.11 *JALCA* 118(11), 452–500, 2023

Contents

Communications for Journal Publication

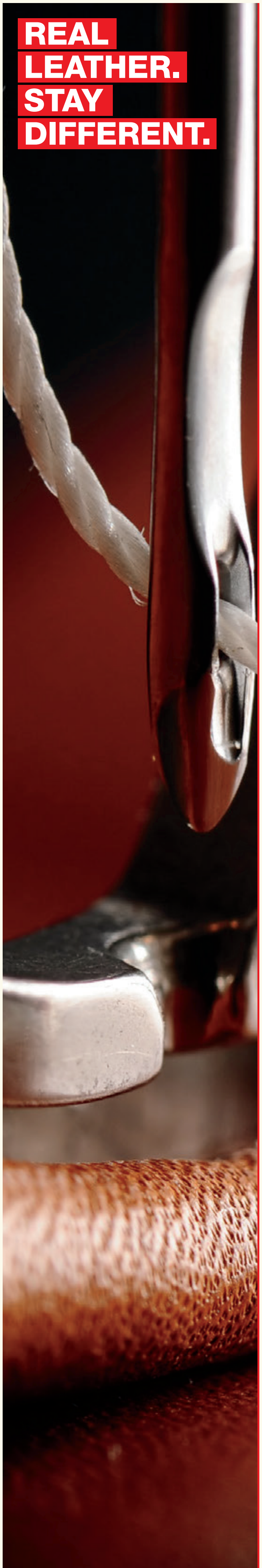
Manuscripts, Technical Notes and Trade News Releases should contact:
Mr. Steven D. Lange, Journal Editor, c/o University of Cincinnati, 5997 Center Hill Ave., Bldg. C, Cincinnati, OH 45224, USA
E-mail: jalcaeditor@gmail.com Mobile phone: (814) 414-5689

Contributors should consult the Journal Publication Policy at:
http://www.leatherchemists.org/journal_publication_policy.asp

Distributed by
University of CINCINNATI
LIBRARY PUBLISHING SERVICES

An imprint of the University of Cincinnati Press

ISSN: 0002-9726



LEATHER BY NUMBERS:

FACTS AND FIGURES FROM THE US LEATHER INDUSTRY AND BEYOND

Note: All figures as of January 2021 or latest available.

ZERO cattle are killed to make US leather. US hides have been valued at JUST 1-2% of a cow's total value for the last two years, which is why they are considered a by-product and often end up as waste. The average price per head of US cattle is $2,000-2.200, while hides vary in price from $5 TO $35 PER PIECE, if sold at all. (1)

330M hides come from the meat and dairy industries around the world. Approximately **34M** were processed the US. (2) **AS MANY AS 2.4M US HIDES** ended up as landfill in 2019, this is **7%** of the national total.

Worldwide the waste figure is approximately **40%** or **132M** hides. With the average hide weighing 25Kg this means that **3M TONNES** are thrown away ever year.

Leather production turns more than **4.5M TONNES OF** potential waste, every year, into usable, durable goods. This saves **2.7M TONS OF GREENHOUSE GAS EMISSIONS** from landfill sites. (3)

Production, processing and distribution of hides and leather products directly employs an estimated **5,486** individuals, who collectively earn more than **$384M**. US exports of hides and leather was over **$1.5BILLION** in 2021. (4)

The US exports approximately **95%** of all cattle hide and wet blue leather products it produces, worth **$2.85BILLION**. (5)

Around **45%** of global leather production is used to make footwear, **22%** for clothing, bags and accessories, **18%** for car upholstery, and about **15%** for furniture. (6)

Water consumption for the production of leather from cattle hides has fallen by more than **35%** in the past 25 years, down from **60 CUBIC-METERS** per ton of hides to **38 CUBIC-METERS** per ton. US tanneries are required, by law, to connect to effluent treatment plants to prevent pollution. (7)

Leather will biodegrade in **LESS THAN 50 YEARS**. In contrast, it can take **500 YEARS** or more for synthetics, made from petrochemicals, to degrade. (8)

ReFed's conversion rate for food waste is for **EACH METRIC TON OF WASTE DISPOSAL** there is **9.8 7MT** of **CO2 EQUIVALENT** emitted. In this case, mostly as methane. (9)

This factsheet is produced by the Leather and Hide Council of America (L&HCA), established to promote the US leather industry which is responsible for a significant proportion of the international trade in hides. The L&HCA works to establish best practice in US leather production and to share this worldwide. Figures quoted refer to the USA unless otherwise stated.

SOURCE:

(1) https://downloads.usda.library.cornell.edu/usda-esmis/files/rx913p88g/w0893q25p/5d86qb66f/lstk0223.pdf

(2) https://downloads.usda.library.cornell.edu/usda-esmis/files/r207tp32d/pg15cj85z/hd76t466z/lsan0422.pdf

(3) 2020 LHCA Infographic

(4) John Dunham & Associates, Economic Impact of the Meat Industry (2016)

(5) https://thesustainabilityalliance.us/wp-content/uploads/2020/04/US-Hide-Skin-and-Leather-Factsheet-0420.pdf

(6) TBC

(7) 2020 LHCA factsheet

(8) https://en.wikipedia.org/wiki/Leather#:~:text=Leather%20biodegrades%20slowly%E2%80%94taking%2025,or%20more%20years%20to%20decompose

(9) https://insights-engine.refed.org/impact-calculator?inputs=%7B%22sector%22%3A%22manufacturing%22%2C%22type%22%3A%22fresh-meat-seafood%22%2C%22unit%22%3A%22tons%22%2C%22alternative%22%3Afalse%2C%22destinations%22%3A%5B%7B%22key%22%3A%22refuse-discards%22%2C%22current%22%3A1%7D%5D%7D

JOURNAL OF THE

AMERICAN LEATHER CHEMISTS ASSOCIATION

Proceedings, Reports, Notices, and News
of the
AMERICAN LEATHER CHEMISTS ASSOCIATION

THE JOURNAL OF THE AMERICAN LEATHER CHEMISTS ASSOCIATION (USPS #019-334) is published monthly by The American Leather Chemists Association, c/o University of Cincinnati, 5997 Center Hill Ave., Bldg. C, Cincinnati, Ohio 45224. Telephone (513) 290-2505. Single copy price: $10.00 members, $20.00 non-member plus shipping and handling. Subscriptions: $185 for hard copy plus postage and handling of $60 for domestic subscribers and $70 for foreign subscribers; $220 for ezine only; and $240 for hard copy and ezine plus postage and handling of $60 for domestic subscribers and $70 for foreign subscribers.

Periodical Postage paid at Cincinnati, Ohio and additional mailing offices. Postmaster send change of addresses to The American Leather Chemists Association, c/o University of Cincinnati, 5997 Center Hill Ave., Bldg. C, Cincinnati, Ohio 45224.

Website: www.leatherchemists.org E-mail: hallks@ucmail.uc.edu

COLD
Milling

Smooth Leather Milling

Erretre
Tannery Innovations

Erretre s.p.a. | Via Ferraretta,1 | Arzignano (VI) 36071 | tel. +39 0444 478312 | info@erretre.com

A Method and Principle of Soft and Transparent Leather Manufacturing

by

Xiu He [1,2] and Jinwei Zhang[1,2]*

[1]*Key Laboratory of Leather Chemistry and Engineering of Ministry of Education, Sichuan University,* Chengdu 610065, P. R. China.

[2]*College of Biomass Science and Engineering, Sichuan University,* Chengdu 610065, P. R. China.

Abstract

For preparing a new kind of leather with transmittance and softness at the same time, glycerol was used to treat delimed and bleached split pelt. The softness, transmittance and mechanical properties were tested to evaluate the performance of soft and transparent leather (STL). FT-IR, SEM, XRD, DSC and TG were used to character the structure of STL and reveal the basic principle of STL manufacturing. The results showed that 25% glycerol based on limed pelt weight could make leather soft and transparent simultaneously. Pig pelt was more suitable for thin and transparent leather while cattle split was better for uniform and clear leather. Glycerol combined with collagen through multipoint hydrogen bonds, and the combination had slight positive effect on improving STL thermal stability. Fiber bundles of STL trended to disperse and collagen hierarchical structure including triple helix remained during transparent treatment. The soft and transparent leather could be a new choice for leather goods designers and might be a selectable substrate for high-performance electronic skin.

Introduction

Leather is a kind of natural polymer network mainly consisting of collagen matrix.[1] Generally, beamhouse, tanning, post tanning and finishing are chief sections for converting raw hides and skins into leather. In leather manufacturing, the raw hides and skins or leather are almost opaque at times, but it is translucent under certain processes such as liming and acid swelling. Leather is usually opaque no matter what kind of tanning method is used. However, some special kinds of skin or leather products are transparent, for example parchment,[2] drum skin and traditional Chinese shadow puppet.[3] Greasy skins (sheep skin, pig skin, monk skin and so on) with improper preservation would become semitransparent. Gelatin or collagen hydrolysate is transparent more or less after drying.[4-6]

Up to now, it has been impossible for leather to be transparent and soft at same time. Soft leather is opaque, and transparent leather or skin is nearly rigid and brittle. If leather could be soft and transparent simultaneously, it could be a new choice for designing new fashion leather goods, the transparent parts which are usually plastic now. Meanwhile, soft and transparent leather could be used for preparing electronic skins.[7]

As is well known, dried raw hides or skins look transparent but feel hard and the reason could be summarized as collagen fibers bond with each other when water is evaporated. In order to solve this problem, a lubricant material could be used to prevent collagen fibers bonding after drying, thus soft and transparent leather (STL) could be prepared. Polyol materials were used for solving the problems of water dehydration and crystallization in hydrogels.[8-10] Based on the properties of polyol materials, it could be inferred that they might be used as lubricants for STL manufacturing.

Up to now, there has been little research about transparent leather and the manufacturing method was missing. In this work, fully washed deliming pelt was treated with glycerol to prepare STL and the softness, transparency and mechanical properties were measured. In addition, FT-IR, SEM, XRD, DSC and TG were used for deducing the principle of STL manufacturing.

Experimental

Materials

Limed bovine hide split with thickness 2.0 mm and pig skin split with thickness 1.5 mm were bought from local tannery in Chengdu, Sichuan province, China. Glycerol and formic acid were provided by Chengdu Kelong Chemical Co. LTD. All chemicals used for preparing deliming pelt were industrial reagents, and the chemicals utilized for testing were commercially available of analytical grade.

Sample preparation

Soft and transparent leather preparation

Limed bovine hide split and pig skin split were trimmed and weighed at first, and then subjected to deliming, bleaching and transparent treatment to prepare STL in drum.[11, 12] The detail process of STL

*Corresponding author email: scutanner@163.com

Manuscript received April 21, 2023, accepted for publication May 28, 2023.

manufacturing is shown in Table I. The dosage of chemicals used in each process was based on the weight of limed pelt.

TM was an ammonium free deliming agent and DW was a nonionic degreasing agent from Sichuan Decision New Material Technology Co., Ltd. China.

The pelt without transparent treatment and toggling until dried directly was regard as Control Sample.

Testing methods

Transmittance measurement

The transmittance of both STL and Control Sample was measured by a WGT-S transmittance and haze tester (Jinan Saicheng Electronic Technology Co., Ltd, China) following the manufacturer's direction according to standard method.[13]

Mechanical properties measurement

Both STL and Control Sample were conditioned as the standard method before mechanical properties testing. The mechanical properties like tensile strength, elongation at break and tear strength were tested by AI-7000S tensile machine (GOTECH testing Machines Inc. China), and the softness was tested by measuring GJ9E1 apparatus for leather softness (GOTECH testing Machines Inc. China) following standard .[14]

FT-IR measurement

STL and Control Sample were tested by a Nicolet 10 FT-IR (Thermo Scientific Corporation, American) in the wavelength range from 500 to 4000cm^{-1} for 32 times.

Scanning electron microscope (SEM) observation

A JSM-7500F scanning electron microscope (Japan Electronic Co., Ltd., Japan) was used for producing leather cross section

Table I

STL manufacturing process

Process	Material	Dosage (%)	Temperature (°C)	Time (min)	Remark
Pre-deliming	water	150	30		
	TM	1			float pH about 9.5, drain
	DW	0.1		30	
Deliming	water	70	33		
	DW	0.2			
	ammonium sulphate	2.5		80	float pH 7.5-8.0, cross section colorless checked with phenolphthalein indicator, drain
Washing	water	300	25	10	twice
Bleaching	water	70	35		
	Sodium carbonate	0.5		10	float pH about 9.5
	hydrogen peroxide	2		20	float pH higher than 9.0
	hydrogen peroxide	2		60	drain
Washing	water	300	25	10	twice
Transparent treatment	water	60	25		
	glycerol	25		300	O/N
	formic acid	0.3		30	
	formic acid	0.3		60	
	formic acid	X		60	float pH 4.0-4.2
Toggling under 30-35°C until dried completely.					

images by operating the SEM at low vacuum with an accelerating voltage of 15 kV.

X-ray diffraction scanning (XRD) determination

The 20mm×20mm samples were tested by EMPYREANX-ray diffraction scanning meter (PANalytical B.V., Netherlands) with diffraction angle 2θ from 5° to 60° with a scanning rate of 2°/min at ambient temperature and humidity.

Thermal properties determination

The dried leathers were put into Aluminum crucibles and heated by a NETZSCH DSC 200 PC differential scanning calorimeter (Germany) with heating rate 5°C/min in a N_2 atmosphere (flow N_2: 100 mL/min). The range of temperature was from 25° to 250°C.

The dried samples were put into ceramic crucibles and heated by a NETZSCH TG 209 F1 thermal gravimetric analyzer (Germany) with heating rate 10°C/min in a N_2 atmosphere (flow N_2: 100 mL/min). The range of temperature was range from 40° to 800°C.

Results and Discussion

Performance of soft and transparent leather

After a huge number of trials, the dosage of glycerol in STL manufacturing process was optimized and 25% glycerol based on weight of liming pelt was selected. Less glycerol resulted in poor softness and transmittance, and more glycerol would make STL feel moist. The performance and images of pig STL are shown in Figure 1. The left two photos illustrate the STL is transparent and the right two photos show the STL is soft. It was clear that the

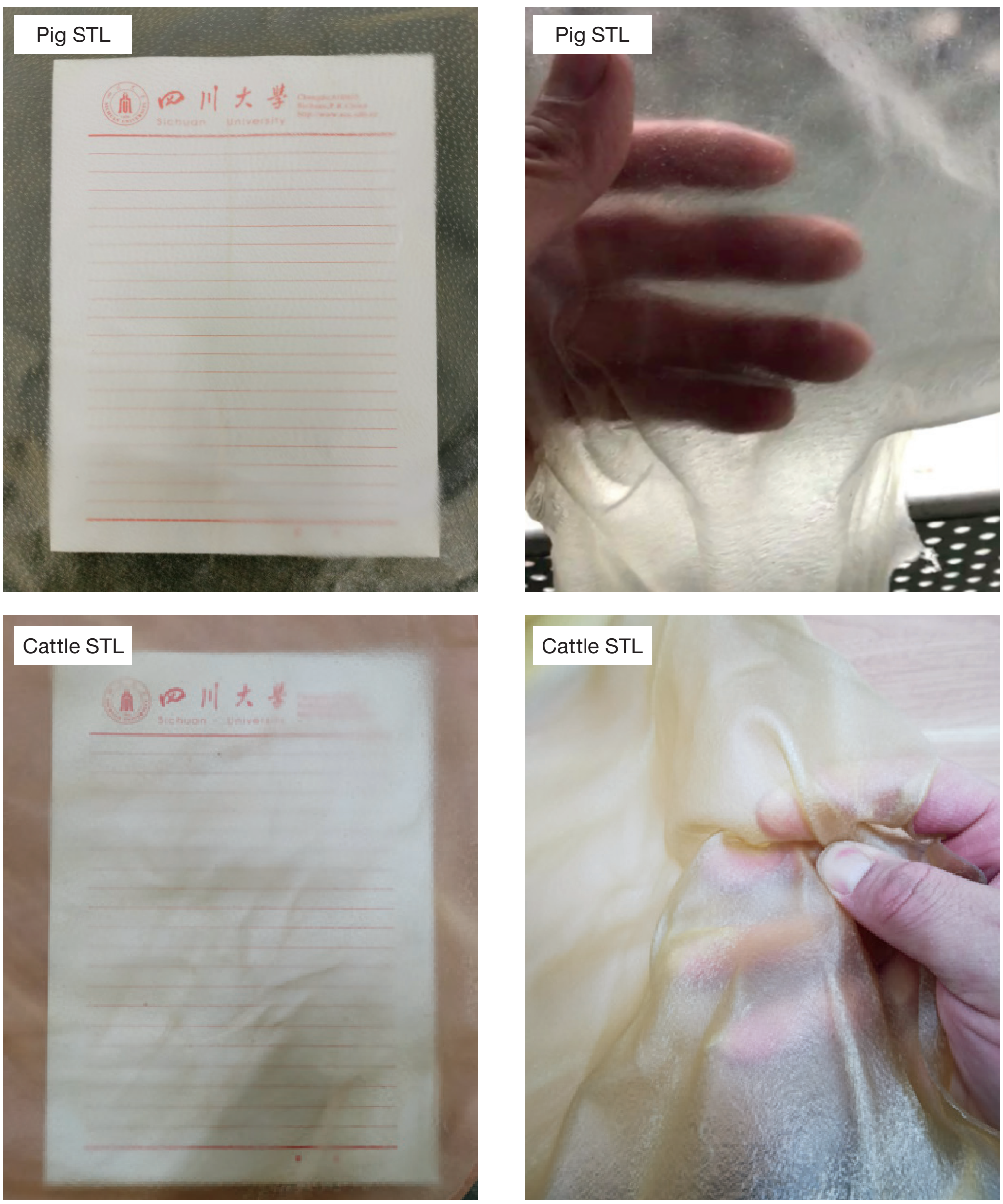


Figure 1. Performance and images of soft and transparent leather

Table II
mechanical properties of soft and transparent leather

Parameters	Cattle STL	Pig STL
Transmittance (%)	78.4	86.5
Softness (mm)	3.88	4.34
Thickness (mm)	0.885	0.442
Tensile strength (MPa)	33.62	25.91
Elongation at break (%)	22.17	23.86
Tear load (N)	20.58	17.57

leather was soft and transparent when glycerol was used to treat pig split pelt. The application of glycerol not only made leather soft but also improved the transmittance of leather. The STL was soft compared with dried pelt and transparent compared with conventional leather.

The mechanical properties of both cattle and pig STL were tested and the results are listed in Table II. As shown in Table II, the softness and transmittance of pig STL were better than cattle STL, but its tensile strength and tear load were slightly lower. As the fiber weaving of pig skin was tighter and denser than cattle hide, much thinner pig split could be obtained. Consequently, the thinner pig pelt might be more suitable for manufacturing soft and transparent leather. On the other hand, since cattle splits almost consist of pure collagen fiber and there was no hair follicles in cattle hides which prevent light scattering and refringence inner leather, the appearance of cattle STL had better uniformity and clarity. In short, the mechanical properties of pig and cattle STL were comparable, and pig pelt was more suitable for thin and transparent leather while cattle split was better for uniform and clear leather.

Structure of soft and transparent leather

Interaction between collagen and glycerol

The FT-IR images of pig STL and Control Sample were shown in Figure 2. It was obvious the absorption peak intensity around 3300 cm^{-1} was enhanced after glycerol treatment, indicating more hydrogen bonds formed between collagen and OH-groups of glycerol. In other words, the interaction between pelt and glycerol was mainly hydrogen bonds.

Figure 2 also illustrates that the collagen structure remained during transparent treatment. The absorption bands at around 1650 cm^{-1}, 1550 cm^{-1} and 1150 cm^{-1} were characteristic of collagen amide I band (stretching vibration of C=O coupled with hydrogen bonding), amide II band (bending vibration of N–H and stretching vibration of C–N) and amide III band (stretching vibration of C–O or C–N–C) respectively,[15] and they were the evidence of a collagen backbone. Moreover, no significant shift of the amide I band was observed, showing the triple helix structure of collagen was not impacted after transparent treatment.

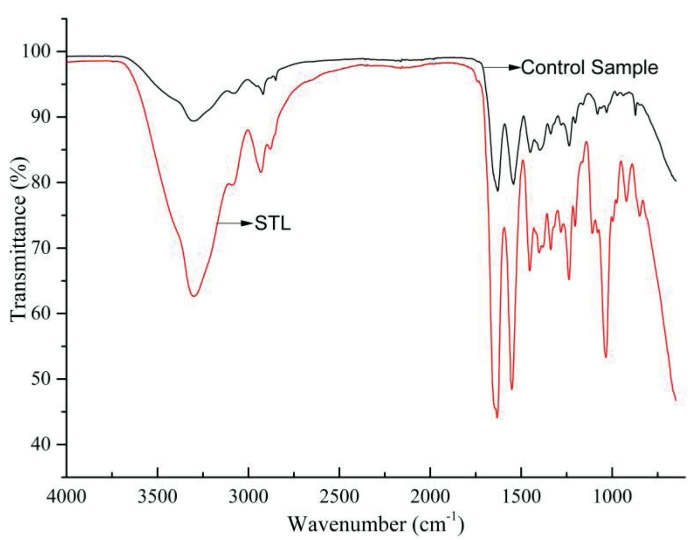


Figure 2. FT-IR images of pig STL and Control Sample

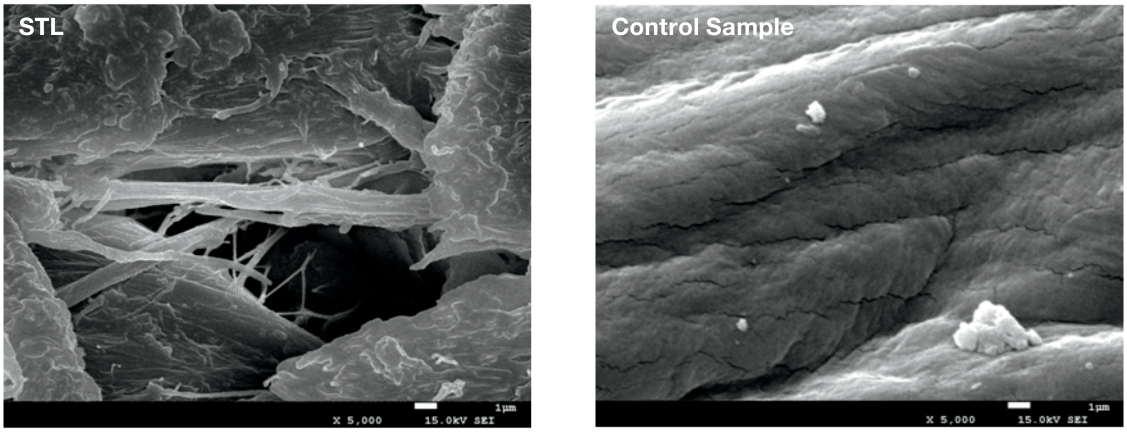


Figure 3. SEM images of pig STL and Control Sample

Histological structure of soft and transparent leather

In Figure 3, collagen fibers of STL appeared to be dispersed and while in the Control Sample they were adhesive. As glycerol was combined with collagen through multipoint hydrogen bonds, it could prevent fibers from adhering during the drying process and lubricate collagen fibers as water was removed. Thus, STL was soft macroscopically. The Control Sample was hard and brittle because there was no lubricant distribution between collagen fibers after evaporation of water during drying. However, the dispersion degree of fiber bundles and porosity of STL were poorer than any leather tanned by any representative tanning agent (chromium, vegetable tanning or aldehyde, etc) as tanning agents could open up the microfibrils, fibrils, elementary fibers and fiber bundles.[16] It could be inferred that the multipoint hydrogen bonds between collagen and glycerol were too weak to generate cross-linking effect.

Crystal structure of soft and transparent leather

Figure 4 indicated there were two peaks in both STL and Control Sample. The one was about 7°, representing the distance between molecular chains, and the other was around 21°, corresponding to diffuse scatter of collagen.[17] According to Bragg equation $2d\sin\theta = n\lambda$, larger 2θ meant the distance between collagen was shorter under same testing condition. A value of 2θ for the Control Sample about 7° was obviously higher than STL, indicating the collagen fibers adhere to each other without glycerol. Hence, the Control Sample was hard and brittle macroscopically. On the contrary, 2θ of Control Sample around 21° was obviously lower than STL, indicating the amorphous area of collagen fibers in STL was enlarged due to glycerol preventing the leather fibers shrink during drying.

Thermal stability of soft and transparent leather

According to DSC results illustrated in Figure 5, the thermal denaturation temperature of STL was much higher than Control Sample, which could match chrome tanned leather. Although glycerol had positive effect on improving thermal stability collagen to some extent,[18] this excellent denaturation temperature could not be attributed to tanning effect because the cross-linking

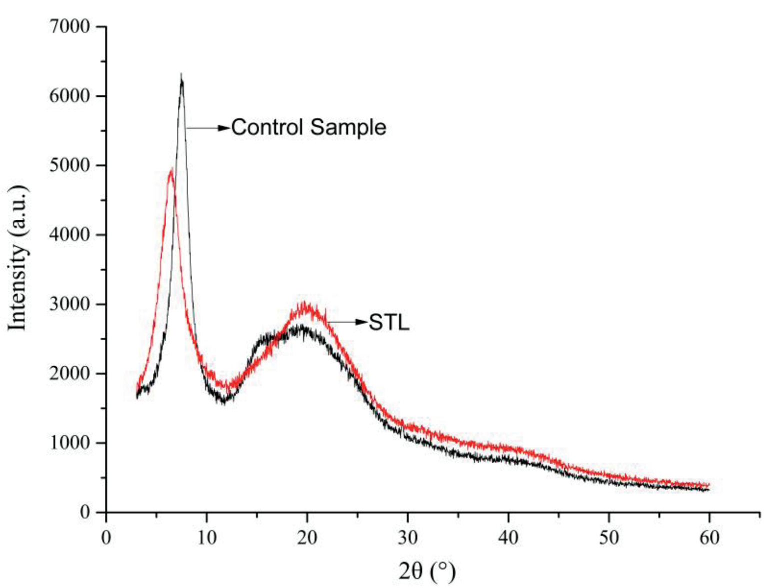


Figure 4. XRD images of pig STL and Control Sample

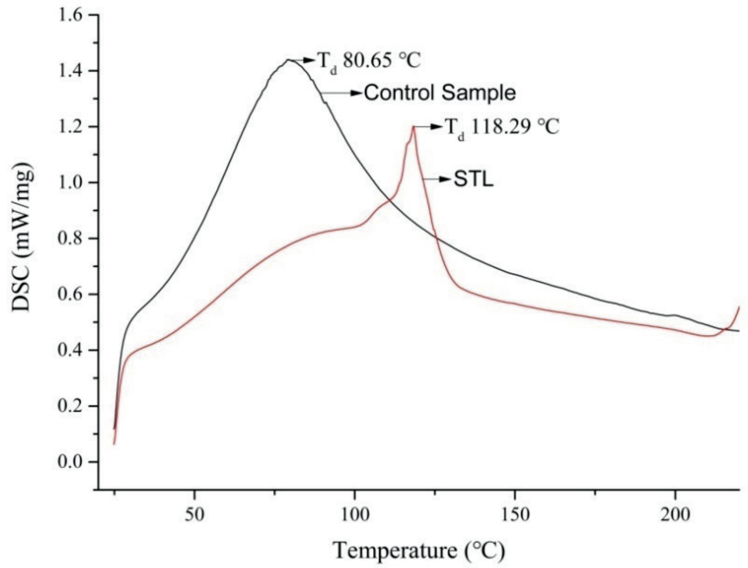


Figure 5. DSC results of pig STL and Control Sample

between collagen molecules could not be generated by glycerol. The reasonable interpretation might be that glycerol absorbed heat before collagen and then resulted in thermal denaturation delay. For Control Sample, collagen absorbed heat directly and the thermal denaturation occurred immediately.

The Thermogravimetric analysis results of pig STL and Control Sample are shown in Figure 6. It is obvious there are two peaks during STL thermal decomposition process; the first one is 237.28 °C which is the thermal decomposition of glycerol according to prior study,[19] and the second one is 314.70 °C. Only one maximum decomposition temperature (T_{max}) of Control Sample (310.07 °C) was observed during TG test. T_{max} near 310 °C was the temperature of collagen decomposition,[20] and the higher T_{max} STL might be the reason that the existence of glycerol could promote thermal stability of biomass.[21] Thermogravimetric analysis also proved that glycerol interacted with collagen successfully.

Mechanism of soft and transparent leather manufacturing

The mechanism of soft and transparent leather manufacturing could be summarized as follows. Glycerol combined with collagen through multipoint hydrogen bonds in the role of lubricant. Glycerol prevented collagen fiber bundles from adhering when water was almost completely removed after drying and resulted in soft and transparent leather. However, two questions about the relationship between leather structure and transmittance are still essentially unknown. First, why could glycerol make leather become transparent while the leather was opaque without glycerol? One possible reason could be inferred as: glycerol filled the air voids of leather and reduces the index of refraction; therefore the visible light could pass through easily with less scattering. Second, why was the leather tanned by any tanning agent opaque? One possible hypothesis was that collagen crystal structure was changed due to new chemical bonds generated during tanning. It would benefit the production of transparent leather with better performance and improved understanding of the tanning mechanism after answering the two questions and confirming the two preliminary speculations above.

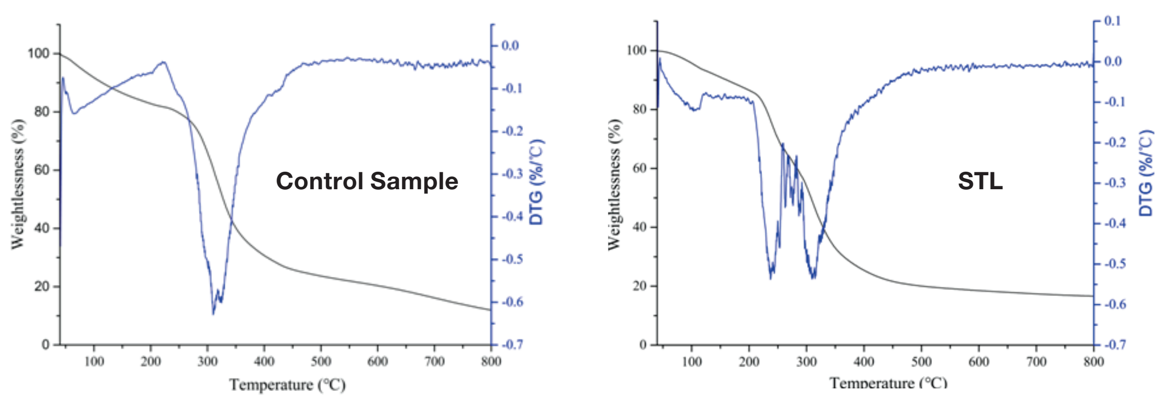


Figure 6. TG results of pig STL and Control Sample

Conclusions

Both cattle hide split and pig skin split could be used to prepare soft and transparent leather when 25% glycerol based on limed pelt weight was used for treating delimed and bleached split pelt. The leather was soft and transparent when compared with traditional leather which had incompatible softness and transmittance. Pig pelt was more suitable for thin and transparent leather while cattle split was beneficial to create uniform and clear leather. Glycerol combined with collagen through multipoint hydrogen bonds and the combination had slight positive effect on improving leather thermal stability. Fiber bundles of soft and transparent leather tended to be dispersed and the collagen hierarchical structure including triple helix preserved during transparent treatment. The soft and transparent leather could be a brand-new choice for leather goods designers and might be an optional strategy for high-performance electronic skin.

Acknowledgements

The authors wish to thank the funding of research institutes of leather and footwear industry of Wenzhou (No. 202008GT02) for financial support.

References

1. Yang, N., Ma, J. Z., Shi, J. B., *et al.*, Manipulate the nano-structure of layered double hydroxides via calcination for enhancing immobilization of anionic dyes on collagen fibers. *Journal of Colloid and Interface Science* **610**, 182-193, 2022.
2. Bagir, M., Eskandari, M. M., Longitudinal extensibility of the dorsal skin of the hand. *Journal of Hand Surgery-European Volume* **44**, 1013-1018, 2019.
3. Guo, S., Pang, X. Y., Ding Z. W., *et al.*, Application of blue polymer dye on transparent leather. *China Leather*, **51**, 29-32, 39, 2022
4. Ungureanu, C., Ionita, D., Berteanu, E., *et al.*, Improving natural biopolymeric membranes based on chitosan and collagen for biomedical applications introducing silver. *Journal of the Brazilian Chemical Society*, **26**, 458-465, 2015.
5. Wang, G. H., Hao, L. L., Zhang, X. D., *et al.*, Flexible and transparent silver nanowires/biopolymer film for high-efficient electromagnetic interference shielding *Journal of Colloid and Interface Science* **607**, 89-99, 2022.
6. Puccini, M., Castiello, D., Seggiani, M., *et al.*, Properties of thermoplastic blends with polypropylene and collagen hydrolysate. *Advanced Materials Research* **893**, 235-240, 2014.
7. Bai, Z. X., Wang, X. C., Zheng, M. H., *et al.*, Mechanically robust and transparent organohydrogel-based e-skin nanoengineered from natural skin. *Advanced Functional Materials* DOI10.1002 /adfm.202212856, 2023.
8. Morelle, X. P., Illeperuma, W. R., Tian, K., *et al.*, Highly stretchable and tough hydrogels below water freezing temperature. *Advanced Materials* **30**, DOI10.1002/adma.201801541, 2018.
9. Guo, M. L., Wu, Y. P., Xue, S. S., *et al.*, A highly stretchable, ultra-tough, remarkably tolerant, and robust self-healing glycerol-hydrogel for a dual-responsive soft actuator. *Journal of Materials Chemistry A*, **7**, 25969-25977, 2019
10. Yu, J., Feng, Y. F., Sun, D., *et al.*, Highly conductive and mechanically robust cellulose nanocomposite hydrogels with antifreezing and antidehydration performances for flexible humidity sensors. *ACS Applied Materials & Interfaces***14**, 10886-10897, 2022.
11. Zhang, J. W., Chen W. Y., A transparent leather and its manufacturing method. *Chinese Patent*, ZL 2018109131980, 2020.
12. Zhang, J. W., Chen W. Y., A method for producing transparent leather. *Chinese Patent*, **ZL 20201026**74593, 2021.
13. ASTM D1003-21. Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics, USA, 2021.
14. Zhang, J. W., Zhang C. L., Wu J. C., *et al.*, The influence of microwave non-thermal effect on leather properties in drying. *JALCA* **112**, 135-139, 2017.
15. Xiao, Y. H., Zhou, J. J, Wang, C. H., *et al.*, Sustainable metal-free leather manufacture via synergistic effects of triazine derivative and vegetable tannins. *Collagen & Leather* **5**, https://doi.org/10.1186/s42825-022-00108-0, 2023.
16. He, X., Ding, W., Zeng, Y. H., *et al.*, Insight into the correlations between fiber dispersion and physical properties of chrome tanned leather. *JALCA* **115,** 23-29, 2020.
17. Zhang J. W., Chen W. Y., A faster and more effective chrome tanning process assisted by microwave. *RSC Advances* **10**, 23503-23509, 2020.
18. Penkova, R., Goshev, I., Gorinstein, S., *et al.*, Stability of collagen during denaturation. *Journal of Protein Chemistry* **18**, 397-401, 1999.
19. Castello, M. L., Dweck, J., Aranda, D. A. G., Kinetic study of thermal processing of glycerol by thermogravimetry. *Journal of Thermal Analysis and Calorimetry* **105**, 737-746, 2011.
20. Yang, P. Y., He, X. C., Zhang, W. J., *et al.*, Study on thermal degradation of cattle hide collagen fibers by simultaneous TG-MS-FTIR. *Journal of Thermal Analysis and Calorimetry* **127**, 2005-2012, 2017.
21. Liu, R., Morrell, J. J., Yan, L., Thermogravimetric analysis studies of thermally-treated glycerol impregnated poplar wood. *Bioresources* **13**, 1563-1575, 2018.

Anti-Ectoparasite Activity of Medicinal Herbal Plant in Terms of Reducing Ectoparasites Effect on Sheep and Goat Skins

by

Fitsum Etefa Ahmed,[1*] Aschalew Shitu,[3] Zerihun Teshome,[1] Endalamaw Yihune,[2] Misganaw Bitew[4] and Haile Mekonnen Fenta[5]
[1]*Ethiopian Institute of Textile and Fashion Technology (EiTEX), Bahir Dar University,* Bahir Dar, Ethiopia.
[2]*College of Science, Department of Biology, Bahir Dar University*, Bahir Dar, Ethiopia
[3]*School of Animal Science and Veterinary Medicine, Bahir Dar University*, Bahir Dar, Ethiopia
[4]Bahir Dar Tannery, Bahir Dar, Ethiopia
[5]*College of Science, Department of Statistics, Bahir Dar University*, Bahir Dar, Ethiopia

Abstract

Ethiopia has one of the world's largest livestock resources. However, the effects of disease, inadequate nutrition and management constrain the potential of this resource. Ectoparasites are one of the primary contributing factors in the tanneries for sheep and goat skin rejection. The aim of this study is to assess the impact of medicinal herbal plant extracts on ectoparasites (ticks) on small ruminants in Ethiopia. According to scientific and ethnomedical data gathered from respondents (farmers), the plant species P. dodecandra, E. globulus, C. macrostachyus, J. schimperiana, and C. aurea were used (by farmers) for the study. Phytochemical screening of extracts revealed the presence of flavonoids, alkaloids, phenols and saponins, tannins.

Ticks from small ruminants (i.e goat and sheep) were collected and an in vitro adult tick immersion test was carried out using concentrations of 6.25, 12.5, 25, 50, and 100 mg/ml of all medicinal plant extracts. The temporal tick mortality was observed within 24-hours. In order to compare the results, distilled water and 12.5% amitraz was used as positive and negative controls, respectively. After 24 hours of exposure, P. dodecandra, J. schimperiana, and C. macrostachyus extracts had a moderate (60%) effect on tick mortality; however, C. aurea extract at 100 mg/ml and E. globulus extract at 50 mg/ml and 100 mg/ml had the highest mortality rate (80%). The study found that following in vitro treatment for the studied plants, the mean tick mortality increased considerably with increasing concentration and exposure duration. The existence of phytochemicals (active ingredients) in several plants, such as phenols, flavonoids, alkaloids, tannin, saponin, etc., may be the cause of their anti-ectoparasite effects. The study's findings suggested that these plants might be crucial in reducing the need for chemical based medicines as well as managing the population of resistant ticks in an environmentally friendly manner.

Introduction

In Ethiopia, the agricultural sector has been prioritized by the government for encouraging overall economic growth and reducing poverty.[1] Within agriculture, the livestock subsector provides an opportunity for further growth. The Ethiopian Leather industry depends on its livestock resources, which include 54 million cattle, 25.5 million sheep, and 24 million goats, making it one of the world's largest livestock populations.[2]

The agricultural sector relies heavily on cattle, sheep, and goats as vital sources of revenue. Live animal exports as well as meat, hide, and skin are among Ethiopia's top sources of foreign exchange earnings.[1,3] Ethiopian sheep and goat skins have a good reputation for quality in the international leather market due to their fine grain and compact structure.[1,3-5]

However, due to the deterioration in skin quality brought on by an increase in ectoparasite infestations, the enormous resource potential of sheep and goat skins has been declining.[3,6-8] Parasitic skin infections brought on by ectoparasites including lice, ticks and mange are becoming a serious threat to the tanning industry.[3,5,9-11] A few years ago, tanneries in the country tended to make 70% of processed skins with grades 1-3, while 10% to 20% of the skins were considered to be of low quality.[5,10] However, over the past ten years, only 10-15% of processed skins have been deemed good, with the remainder being either rejected or downgraded as a result of an increase in ectoparasite infestations.[9,12] Consequently, Abunna

Figure 1. Tick on small ruminants

*Corresponding author email: oneday790@gmail.com
Manuscript received March 29, 2023, accepted for publication June 24, 2023.

et al.[13] reported ectoparasite prevalence in sheep (87.5%) and goat (89.9%) in Oromia region, Seyoum[11] reported prevalence in sheep (22.7%) and goat (11.5%) in Amhara region whereas Dawit et al.[14] reported prevalence in sheep (34.1%) and goat (12.2%) in Amhara region, Ethiopia.

The use of synthetic insecticides in the treatment of ectoparasites has become a serious global problem due to the emergence of ectoparasite resistance, the production of non-specific residual products, and environmental pollution. Herbal remedies are being utilized more frequently to treat a variety of ailments due to the perception that green medicine is non-hazardous, accessible, and has fewer negative impacts. The main aim of this research is to assess the effect of medicinal herbal plant extracts on ectoparasites in small ruminants in Ethiopia.

Data collection

A purposive sampling technique was carried out using group focus discussions with sheep and goat producers and field observations to collect indigenous knowledge on traditional healers. Secondary data were collected through a review of the literature published in scientific journals. Descriptive statistics were used to analyze and summarize ethno-botanical data.

Two hundred seventy (270) livestock keepers found in West Gojjam, Amhara Regional state, Ethiopia was consulted to corroborate some of the information related to ectoparasite infestation and treatment. Among these groups, semi-structured questionnaires and informal interviews were undertaken within a period of 10 days. The interviewees were shown pictures of ticks, lice and mange and requested to give the main ectoparasite species that attack their animals, the seasonal occurrence of infestation, ectoparasite species specific attachment sites and details on possible treatment methods. The information gathered shows that farmers are still relying on plant extracts as a source of ectoparasite medication for their livestock. Around 18 plants, which have medicinal value against ectoparasite were reported by farmers and that tick infestation was higher than the other ectoparasites. Cattle, followed by sheep and goats were predominantly treated by plants for worm and ectoparasite infestations. Table I indicates a list of plants used for the treatment of tick infestations in the area.

Table I

List of medicinal plants used for the treatment of ectoparasite in the area

Plant Name	Plants Parts used
Calpurnia aurea	Leaves
Phytolacca Dodecandra	Leaves
Eucalyptus globulus Labill	Leaves
Croton macrostachyus	Leaves
Azadirachta indica A. Juss	Leaves
Justicia schimperiana	Leaves
Kleinia	Leaves
Solanum incanum L.	Leaves
Aloe vera	Leaves
Acokanthera schimperi	Leaves
Clematis hirsuta	Leaves
Rumex nervosus	Leaves
Datura stramonium	Leaves
Lupinus albus	Leaves
Sida rhombifolia	Leaves
Millettia ferruginea	Leaves
Garlic	Leaves
Ginger	Leaves

Experimental

Plant Collection and drying

For the study, five (5) potential plants were chosen based on the ethnomedical information in the literature supplemented with a preliminary ethnobotanical survey during data collection from the respondents. The potential plants used for the experiment were Calpurnia *aurea*, Phytolacca *dodecandra***,** Eucalyptus *globulus*, Croton *macrostachyus* and Justicia *schimperiana*. Fresh leaves of the plants were collected, shade dried for two weeks then crushed using an electric grinder into a fine powder.

Extract Preparation

Each plant powdered material was subjected to separate extraction using methanol solvent. A 100g powder was separately soaked in each extraction solvent (900 ml of solvent). As shown in Figure 2, the resulting solution was then stirred for 72 hrs. using shaker to produce the required mixtures. The mixture was filtered using Whatman No. 1 filter paper, and the extracts were kept in sealed bottles in the refrigerator (4°C) until they were required for further application.[15]

Phytochemical Analysis

Phytochemical analysis was done to determine the presence of secondary metabolites in the plants.[15]

Test for Flavonoids: A small amount of extract was treated with aqueous NaOH and HCl and observed for formation of yellow orange color.[16]

Test for Alkaloids: Mayer's reagent was used to process the extracts (1.36 g of mercuric chloride and 5 g of potassium iodide in 100 ml of water). A few ml of plant sample extract, two drops of Mayer's reagent are added along the sides of test tube. The presence of alkaloids is indicated by the formation of a yellow or white creamy precipitate.[17,63]

Test for phenols: 3 to 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 or dark green color.[17,63]

Test for Tannin: In a test tube, a 2 ml portion of the extract was placed, and the extracts were treated with a few drops of 10% ferric chloride solution and observed for the formation of a blue or dark greenish color.[17,63]

Test for saponins: A 0.5 gm of extracts was 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 1cm layer of foam.[17.63]

Adult Immersion Test

The outcomes of an in vitro susceptibility test on the antiparasitic activity of plant-based materials are influenced by a variety of factors including plant type, method of extraction, test method and environment.[40] Ectoparasites (i.e ticks) attached to small ruminants were collected manually using thumb forceps at district level. Ticks were collected and placed in bottles covered with cotton net gauze. Within an hour of the ticks being collected, the in vitro tests were started. The effectiveness of all medicinal plant extracts as ectoparasiticides was tested in vitro (at the laboratory level) at concentrations of 100, 50, 25, and 12.5 mg/ml. In order to compare the experimental results, Amitraz 12.5% (1:1000) and distilled water were used as positive and negative controls. Five adult ticks were immersed to each extract concentration and incubated at room temperature 26° ± 2°C under a natural photoperiod. Following immersion, each tick was carefully examined for indications of death at intervals of 30 minutes, an hour, two hours, three hours, six hours, twelve hours, and twenty-four hours.[15,41] A needle was used to regularly check the condition of ticks, and if no reaction was observed, the tick was recorded as dead. Then the ecoparasiticidal efficacy of each medicinal plant extract was analyzed. The data were filled in statistical software program (SPSS) and descriptive statistics were used to summarize the ethno-botanical data in terms of tables and graphs.

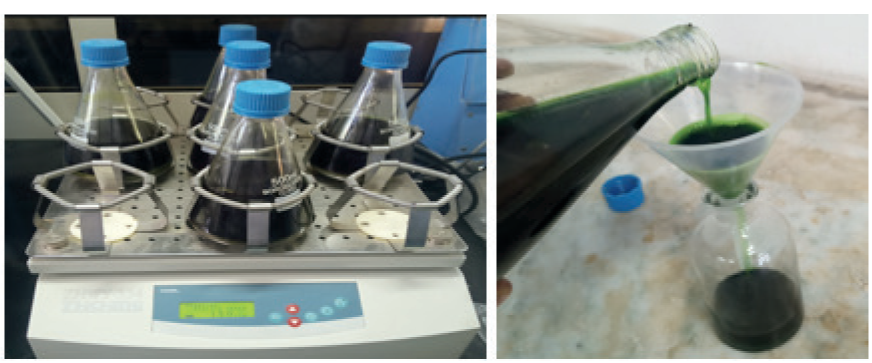


Figure 2. Extract shaking and filtration

Table II

Phytochemical analysis

Compound	Test Method	Methanolic extract				
		C. *aurea*	**P. *dodecandra***	**E. *globulus***	**J. *schimperiana***	**C. *macrostachyus***
Flavonoids	Alkaline reagent[16]	+	+	++	++	++
Alkaloids	Wagner's test[17]	+	+	+	++	++
Phenols	Ferric chloride[17]	+	++	-	++	+
Tannins	Ferric chloride[17]	+	++	++	++	++
Saponins	Frothing[17]	+	+	++	+	+

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

Result and Discussion

Preliminary Qualitative Analysis

As shown in Table II, phytochemical screening of methanolic extracts have significant indication about the presence of secondary plant metabolites such as, phenolic compounds, alkaloids, flavonoids, tannins, saponin, and steroids.

Flavonoids Detection: The phytochemical analysis of methanolic extracts using the alkaline reagent test revealed a strong positive (++) presence of flavonoids in E. *globulus*, J. *schimperiana*, C. *macrostachyus* and a weak positive (+) presence of flavonoids in C. *aurea* extracts as shown in Table II. Correspondingly, different studies revealed the presence of flavonoids in the extract of C. *aurea,*[18] E. *globulus,*[19] J. *schimperiana*[20] and C. *macrostachyus* extracts.[21]

Alkaloids detection: According to Table II, the Mayer's and Wagner's tests showed that the extracts of J. *schimperiana* and C. *macrostachyus* had strong positive (++) alkaloids, whereas the extracts of C. *aurea*, P. *dodecandra*, and E. *globulus* had weak positive (+) alkaloids. Correspondingly, different studies revealed the presence of alkaloids in the extract of C. *aurea,*[18] P. *dodecandra*,[22] E. *globulus,*[23] J. *schimperiana*[24] and C. *macrostachyus.*[25]

Phenols detection: According to Table II, the ferric chloride test indicated that the extracts of P. *dodecandra* and J. *schimperiana* had strong positive (++) phenols, while the extracts of C. *aurea* and C. *macrostachyus* contained weak positive (+) flavonoids. Accordingly, several studies have demonstrated the presence of phenols in the extracts of C. *aurea,*[26] P. *dodecandra,*[22] J. *schimperiana*[24] and C. *macrostachyus.*[27]

Tannin detection: According to the results of the ferric chloride test, strongly positive (++) tannin were detected in the extracts of P. *dodecandra*, E. *globulus*, J. *schimperiana*, and C. *macrostachyus* and weakly positive (++) tannins were detected in C. *aurea*, which were shown in Table II. Consequently, various studies have demonstrated the presence of tannin in the extracts of C. *aurea,*[28] P. *dodecandra,*[29] E. *globulus,*[30] J. *schimperiana*[31] and C. *macrostachyus.*[21]

Saponins Detection:

Following Froth test approach, the extracts of E. *globulus* showed a strong positive (++) saponins, while the extracts of C. *aurea*, P. *dodecandra*, J. *schimperiana*, and C. *macrostachyus* indicated the presence of weak positive (+) flavonoids, which were indicated in Table II. Consequently, several studies have confirmed the existence of saponins in the extracts of C. *aurea,*[18] P. *dodecandra,*[32] E. *globulus,*[33] J *schimperiana*[20] and Croton *macrostachyus.*[27]

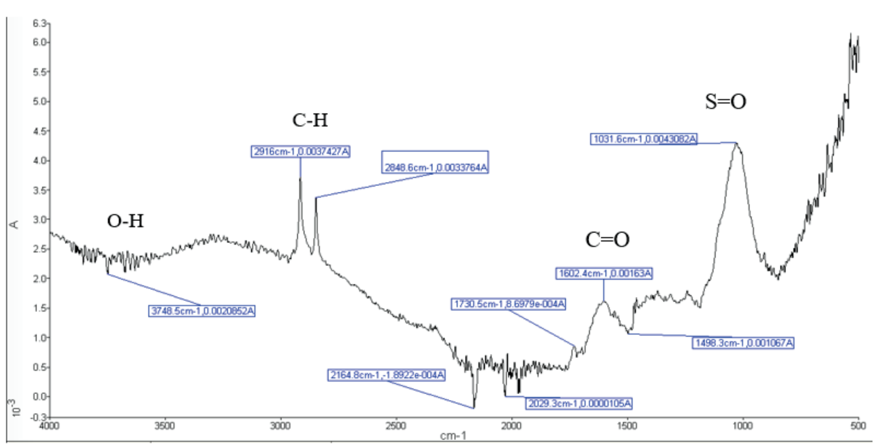


Figure 3. FT-IR absorbance spectrum of Calpurnia aurea

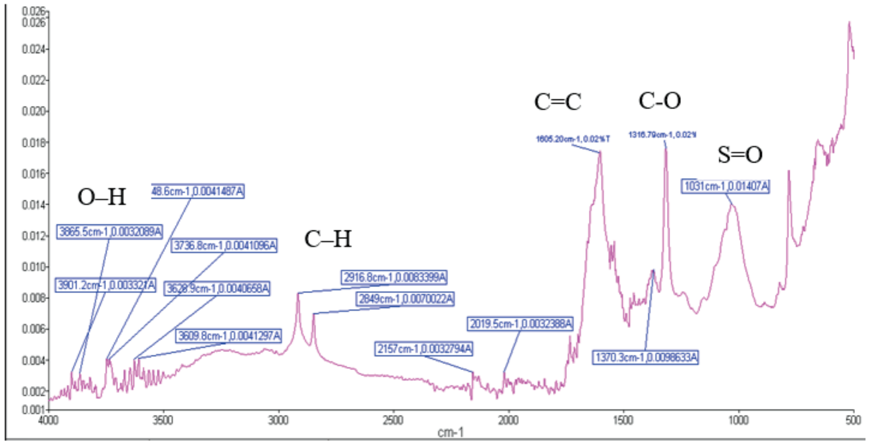


Figure 4. FT-IR absorbance spectrum of Phytolacca Dodecandra

FTIR Analysis

Fourier Transform Infrared Spectroscopy (FTIR) was used to identify different characteristics and functional groups that were present in various materials.[34] The FTIR data spectrum was recorded with a scan speed of 2 mm/s and the powdered plant samples were added as a powder with a wavelength spectral range of 4000cm^{-1}-500 cm^{-1}.[35]

The above Figure 3 shows the functional groups present in the C. *aurea* leaves. In the FT-IR spectrum of C. *aurea*, the region from 2950cm^{-1}-2800cm^{-1} indicate the presence of stretching vibration of C-H of alkane functional groups.[36] The presence of carboxylic acid (O–H stretch) was revealed by the peak 3750 cm^{-1}. The region from 1700cm^{-1}-1500cm^{-1} indicates the presence of asymmetric carboxyl stretching vibration of C=O functional groups.[37] A strong absorption broad peak at 1030^{cm-1} indicate the presence S=O stretching due to sulfoxide functional groups.[38]

As shown in Figure 4, the FT-IR spectrum of Phytolacca D. revealed the presence of carboxylic acid (O–H stretch) at a weak peak at 3750 cm–1 and the medium peak appeared in the range of 2900–2850 cm–1 mainly attributed to the stretching vibration of C–H of alkane. The medium peak appeared at 1606 cm–1 and 1310 cm–1 mainly attributed to C=C stretching vibration and C-O stretching vibration, respectively. The medium stronger peak appears at 1034 cm^{-1} attributed to S=O stretching due to sulfoxide functional groups.

As shown in Figure 5, the FT-IR spectrum of Eucalyptus *globulus* provided a weak peak at 3748 cm^{-1} which indicated the presence of O-H stretching due to alcohols.[34] It showed peaks at about 1622cm^{-1} attributed to C=C stretching due to alkenes. The broad peak at 1034 cm^{-1} attributed to S=O stretching due to sulfoxide functional groups of compound. FT-IR spectrum confirmed the presence of secondary plant metabolites, which are alcohols, phenols, alkenes and sulfoxides in plant extracts.[39]

As shown in Figure 6, the IR spectrum of Justicia *schimperiana* peaks near 3748 cm-1 showed absorption bands assigned to an O-H stretching of alcohol. Two sharp peaks near to 2917 cm-1 and 2849 cm-1 are indicative of C-H stretching of Alkane. It also revealed the presence of a weak anhydride CO-O-CO stretching at 1040 cm-1. Therefore, the IR spectrum depicts the presence of alcohol, alkane and anhydride groups attached to a quaternary carbon in the compound.

As shown in Figure 7, the FT-IR spectrum of Croton *macrostachyus*, the absorption band at 3745 cm-1 indicated the presence of O-H stretching of alcohol whereas the absorption bands at 2917 cm-1 and

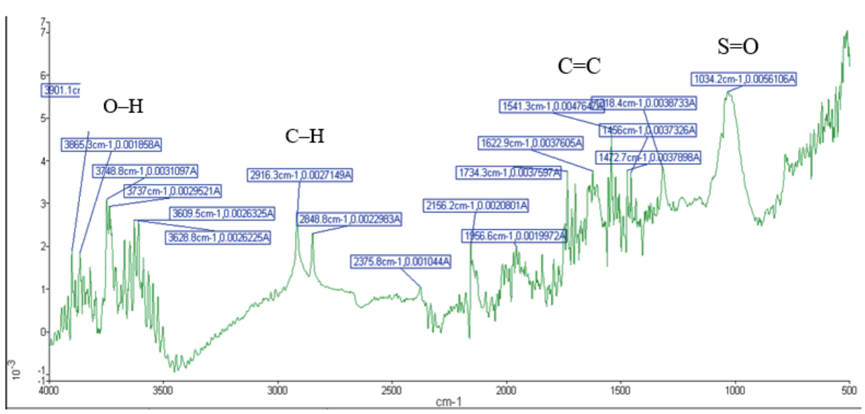


Figure 5. FT-IR absorbance spectrum of Eucalyptus globulus

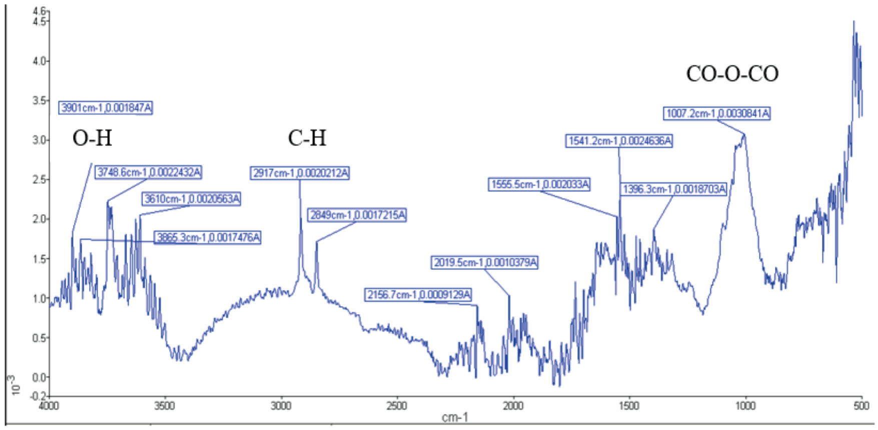


Figure 6. FT-IR absorbance spectrum of Justicia schimperiana

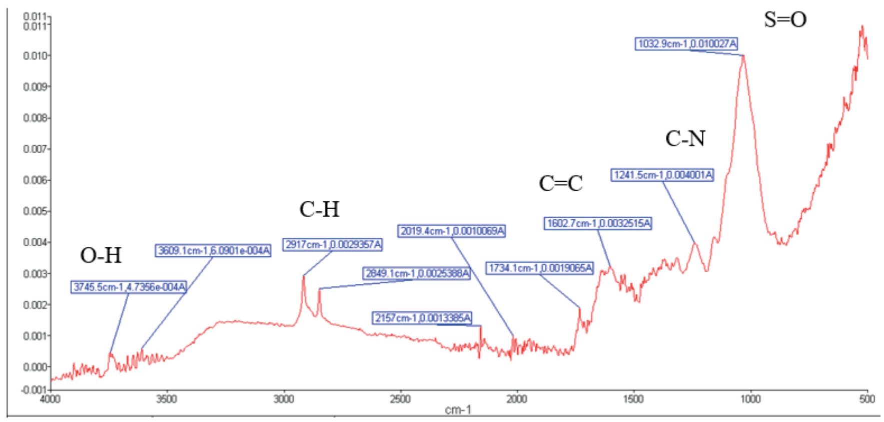


Figure 7. FT-IR absorbance spectrum of Croton macrostachyus

2849 cm-1 indicated the presence of C-H stretching of alkane. The peak at 1602 cm^{-1} attributed to C=C stretching of alkene and 1241 cm^{-1} attributed to C-N Stretching due to amaine functional groups. The broad peak at 1032 cm^{-1} is attributed to S=O stretching due to sulfoxide functional groups.

Adult Immersion Test

Adult immersion tests were conducted in order to identify anti-ectoparasite activity of medicinal herbal plants. As shown in Figure 8, after exposure to Amitraz 12.5% for 1 hour and P. *dodecandra* at concentrations of 50 mg/ml and 100 mg/ml for 6 hours, there was a substantial increase in tick mortality (40%). Less tick mortality (20%) was observed 6 hr post exposure with 12.5mg/ml and 25 mg/ml concentrations of P. *dodecandra* extract.

Figure 8 shows that after exposure to Amitraz 12.5% for 1 hour and P. dodecandra at concentrations of 50 mg/ml and 100 mg/ml for 6 hours, there was a substantial increase in tick mortality (40%). Less tick mortality (20%) was observed 6 hr post exposure with 12.5mg/ml and 25 mg/ml concentrations of P. *dodecandra* extract. At 24 hr

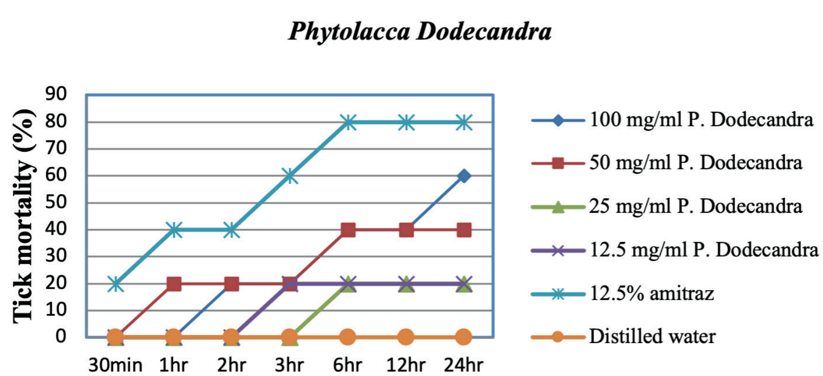


Figure 8. Mortalities of ticks at different time intervals in Phytolacca.Dodecandra extract.

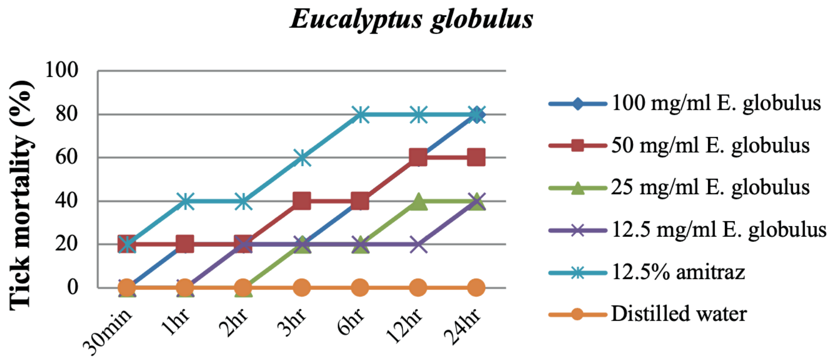


Figure 9. Mortalities of ticks at different time intervals in Eucalyptus globulus extract.

post exposure period Amitraz 12.5% (80%) and 100mg/ml (20%) P. *dodecandra* had the highest tick killing effect compared with the rest of the extract concentrations.

A substantial increase in tick mortality (60%) was observed after 3 hr post exposure with Amitraz 12.5% and 100 mg/ml concentration of E. *globulus* extract, and 6 hr exposure with 50mg/ml and 25 mg/ml concentrations of E. globulus extract (Figure 9). Moderate tick mortality (40%) was observed 6 hr post exposure with 12.5mg/ml, 25 mg/ml and 50mg/ml concentrations of E. globulus extract. Subsequently, after 24 hr post exposure, Amitraz 12.5%, 50mg/ml and 100mg/ml of E. *globulus* extract had the highest tick mortality (80%) effect than the rest of the extract concentrations.

As shown in Figure 10, a substantial rise in tick mortality (40%) began 3 hours after exposure to Amitraz 12.5% and at 6 hours after exposure with 50 mg/ml and 100 mg/ml concentration of J. *schimperiana* extract. At 24 hr post exposure, 50 and 100 mg/ml concentrations of the extract have caused significantly higher tick mortality (60%) than the rest of extract concentrations. At 24hr exposure, the 12.5mg/ml and 25 mg/ml has caused significant tick mortality (40%) than negative control (distilled water).

According to Figure 11, a substantial increase in tick mortality (40%) began 2 hours after exposure with Amitraz 12.5% and 6 hours after exposure with 50 mg/ml and 100 mg/ml concentrations of C. *macrostachyus* extract. After 24 hours exposure, 50 and 100 mg/ml concentrations of Croton *macrostachyus* extract caused

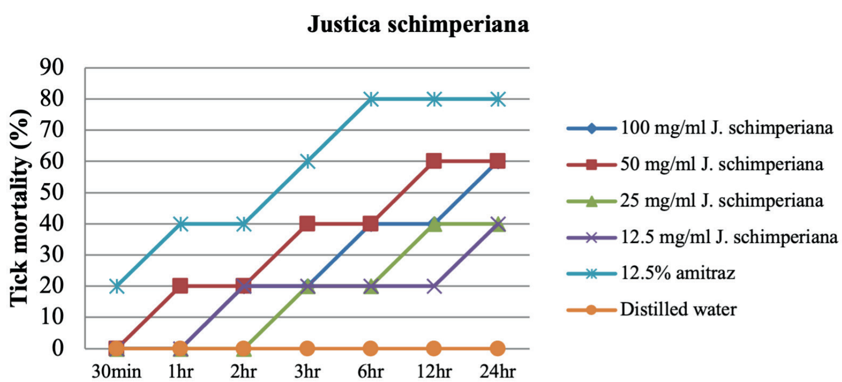


Figure 10. Mortalities of ticks at different time intervals in Justica schimperiana extract.

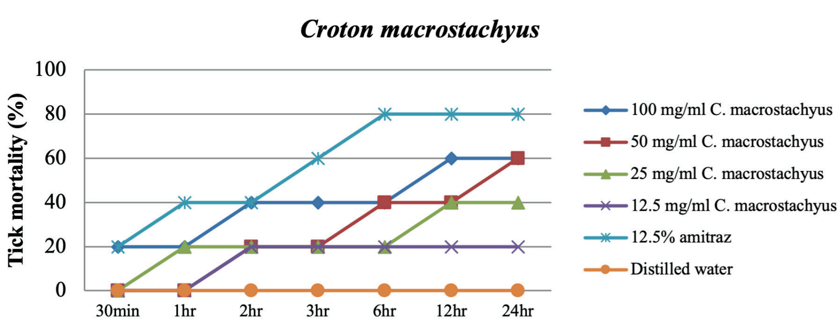


Figure 11. Mortalities of ticks at different time intervals in Croton macrostachyus extract.

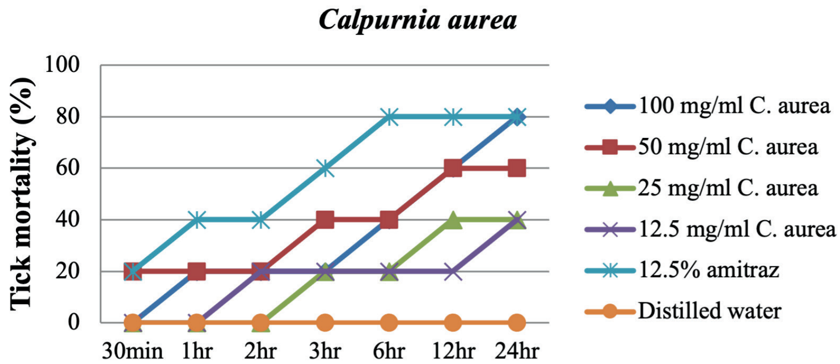


Figure 12. Mortalities of ticks at different time intervals in Croton aurea extract.

a substantial increase in tick mortality (to 60%) compared to the other concentrations. After 24hr exposure, 12.5mg/ml and 25 mg/ml concentrations of Croton *macrostachyus* extract has caused significant tick mortality (20%) than negative control (distilled water).

A significant increase (40%) in tick mortality started 1 hr post exposure with Amitraz 12.5% and 6 hr exposure with 50mg/ml and 100 mg/ml concentrations of C. *aurea* extract (Figure 12). When compared to 25 mg/ml and 12.5 mg/ml concentrations C. *aurea* extract, tick mortality was significantly higher at 24 hours post-exposure with 50 mg/ml and 100 mg/ml concentrations of C. *aurea* extract and Amitraz 12.5%. After 24 hours of exposure, the lowest concentration (12.5 mg/ml) of C. aura showed a substantial increase in tick mortality compared to the negative control (distilled water). The study finding revealed that Calpurinia *aurea* extract has a significant antiparasitic activity against small ruminant ticks. The current findings are similar with Gebrezgabiher et al,[42] Zorloni et al.[43] and Teklay et al.[44] who reported water extracts of Calpurinia *aurea* has insecticidal activity against ticks. Similarly, studies reported that, application of water-based extract of Melia *azedarach* L.,[45] Solanum *incanum* L,[46] Aloe excelsa A. Berger,[12] Nicotiana *tabacum* L.,[47] Azadirachta indica A. Juss,[48] Otostegia integrifolia Benth,[49] Aloe megalacantha Bark,[44] Guizotia *scabra*,[50] Citrus *aurantifolia*,[51] Cassia *nigicans*[52] and Commiphora *erythraea*[53] have insecticidal activity against ticks.

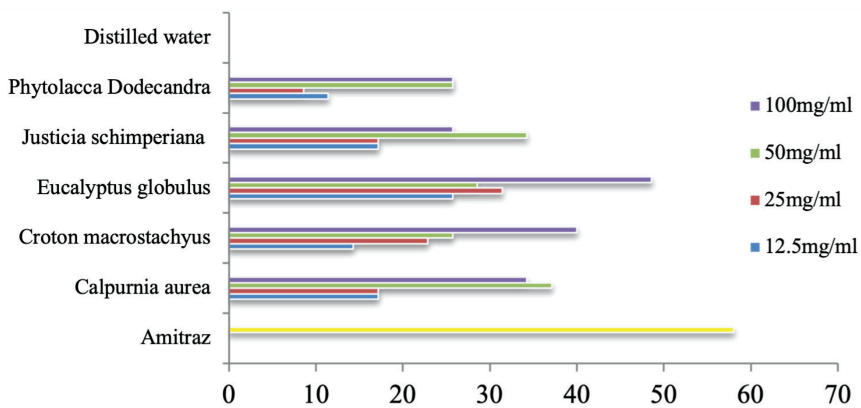


Figure 13. Mean mortalities of ticks at different concentration intervals in different medicinal plant extracts.

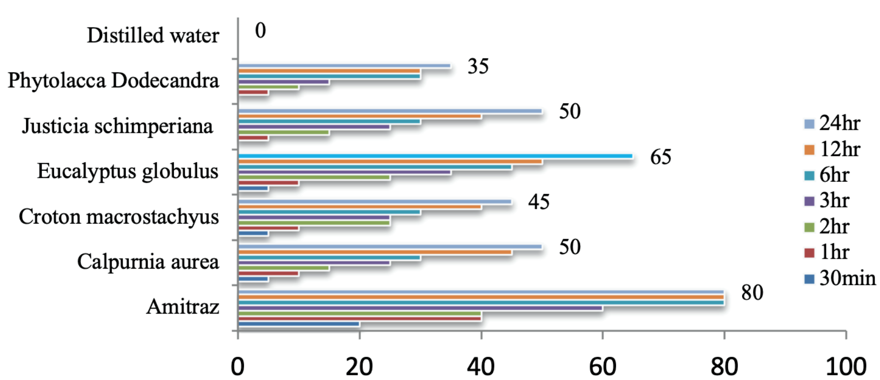


Figure 14. Mean mortalities of ticks at different time intervals in different medicinal plant extracts.

Table III

Two-way analysis of variance (ANOVA)

```
                       Df Sum Sq Mean Sq F value Pr(>F)
plantonly$Plant_extract   4   3589   897.1   2.248 0.0672 .
Residuals             135  53886   399.2
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

As shown in Figure 13, Amitraz 12.5% had the highest tick mortality and followed by Eucalyptus *globulus*. Phytolacca *Dodecandara* showed the lowest tick mortality than the other extracts. The present study revealed that the mean mortality of ticks was increased significantly with increased dosage (concentration) in vitro treatment for the tested botanicals.

The results of the current investigation showed that using higher dosages (concentrations) of the investigated botanicals in vitro considerably increased the mean tick mortality, which were shown in Figure 14. This outcome is consistent with that of Adenubi,[54] who found that the dosages (concentration) and exposure duration had an impact on the mortality effect of plants.

As indicated in Table III and IV, the plant extracts have similar effects on morality rate of ticks and the mean mortality of ticks was increased significantly with increased concentration and exposure time after in vitro treatment for the tested plants.

Mode of Action

Few studies have been carried out to fully understand how these naturally occurring compounds act as anti-ectoparasites, and the mode of action of many compounds derived from plants used for ectoparasite control is not well studied.[55] Several studies report that, presence of phytochemicals (secondary plant metabolites) possess various biological activities including anti-parasitic, antioxidant, anti-bacterial, and antifungal.[56-59] In line with this, the presence of phytochemicals (active components) including phenols, flavonoids, alkaloids, tannin, saponin etc. in different plants, may be responsible candidates for the anti-ectoparasite properties (growth inhibition).[27,60,61] According to de Souza Chagas,[62] phytochemicals may act to counter growth of regulatory hormones, limiting egg growth, causing dehydration, inhibition of breathing (clog airways) and prevent chitin formation. In general, the biology of how the plant essential oils affect ectoparasite remains unexplored and warrants an ideal opportunity to work further on the plant metabolites involved in the process.

Conclusion

The leather sector has a huge potential for employment, and export revenue generation in the world economy. Ethiopia has one of the largest livestock populations in the world. However, this huge resource potential is constrained and threatened by compound effects of ectoparasites, poor management and malnutrition. Using synthetic pesticides to treat ectoparasites has become a critical global issue due to the increasing resistance to pesticides of the ectoparasites and environmental pollution. This study revealed that P. *dodecandra*, E. *globulus*, C. *macrostachyus*, J. *schimperiana* and C.

Table IV

Mean and SD number of ticks mortality at of different time interval and concentration

Extract Concentration (mg/ml)	Mean and SD tick mortality at different concentration and exposure time						
	30min	1hr	2hr	3hr	6hr	12hr	24hr
100mg/ml	8 (10.9)	12 (10.9)	28 (10.9)	32 (17.8)	44 (8.9)	52 (10.9)	68 (10.9)
50mg/ml	4 (8.9)	12 (10.9)	20(0)	28 (10.9)	40 (0)	48 (10.9)	60 (14.1)
25mg/ml	0 (0)	4 (8.9)	8 (10.9)	20 (14)	24 (8.9)	40 (14.1)	40 (14.1)
12.5mg/ml	2.86 (7.5)	8.58(15.7)	17.15(13.8)	22.85(18)	28.57 (25.4)	28.5 (25.4)	34.3 (25)

aurea plants extract have shown good result in tick mortality after 24 h of exposure. Research on plant extracts for use in ectoparasite control has grown in recent years and the plants used in the study are a viable alternative to commercial acaricides.

Competing Interests

The authors declare that they have no competing interests.

Acknowledgments

The authors would like to acknowledge Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University and IULTCS/IUR-YLSG 2022 for the support towards successful completion of the research work.

Reference

1. Adem, M.J.C.F. and Agriculture; Production of hide and skin in Ethiopia; marketing opportunities and constraints: A review paper. *Cogent Food & Agriculture, Taylor & Francis*, **5**(1): p. 1565078, 2019.
2. Leta, S. and Mesele, F., 2014. Spatial analysis of cattle and shoat population in Ethiopia: growth trend, distribution and market access. *SpringerPlus*, **3**(1), pp.1-10.
3. Tolossa, Y.H.J.J.o.V.M. and A. Health; Ectoparasitism: Threat to Ethiopian small ruminant population and tanning industry. *Journal of Veterinary Medicine andAnimal Health*, **6**(1): p. 25-33. 2014.
4. Sheep, C.D.O.; Common Defects of Sheep/Goat Skins in Ethiopia and Their. *CDOF SHEEP*, Technical Bulletin No. 19, 2009.
5. Abebayehu, T., M.J.T.a.h.; Study on ectoparasitic defects of processed skins at Sheba Tannery, Tigray, Northern Ethiopia. *Tropical animal health and production, Springer*, **42**(8): p. 1719-1722, 2010.
6. Yacob, H., T. Yalew, and A.J.R.d.M.V. Dinka.; Part I: ectoparasite prevalences in sheep and in goats in and around Wolaita soddo, Southern Ethiopia. *Revue de Médecine Vétérinaire,* **159**(8-9): p. 450-454, 2008.
7. Shiferaw, S.J.J.V.S.M., An overview of ectoparasites on domestic animals in Ethiopia. *Journal of Veterinary Science & Medicine*, 2018. **6**(1): p. 1-5.
8. Jones, B.A., et al.; Pastoralist knowledge of sheep and goat disease and implications for peste des petits ruminants virus control in the Afar Region of Ethiopia. *Preventive Veterinary, Elsev*ier, **174**: p. 104808, 2020.
9. Sertse, T. and A.J.S.r.r. Wossene.; Effect of ectoparasites on quality of pickled skins and their impact on the tanning industries in Amhara regional state, Ethiopia. *Small ruminant research, Elsevier*, **69**(1-3): p. 55-61, 2007.
10. Berhanu, W., et al.; Assessment on major factors that cause skin rejection at Modjo export tannery, Ethiopia. *Tropical Animal Health and Production*, **43**(5): p. 989-993, 2011.
11. Seyoum, Z., T. Tadesse, and A.J.J.o.v.m. Addisu.; Ectoparasites prevalence in small ruminants in and around Sekela, Amhara Regional State, Northwest Ethiopia. *Journal of Veterinary Medicin*e, 2015.
12. Gemeda, N., et al.; Insecticidal activity of some traditionally used Ethiopian medicinal plants against sheep ked Melophagus ovinus. *Journal of Parasitology Research*, 2014.
13. Abunna, F., et al., Survey of tick infestation in small ruminants of Miesso district, West Harergie, Oromia Region, Ethiopia. *Tropical Animal Health and Production*, **41**(6): p. 969-972, 2009.
14. Dawit, T., et al.; Ectoparasites of small ruminants presented at Bahir dar veterinary clinic, Northwest Ethiopia. *African Journal of Agricultural Research*, Vol. **7**(33), pp. 4669-4674, 28 August, 2012.
15. Kemal, J., et al.; In vitro acaricidal activity of selected medicinal plants traditionally used against ticks in eastern Ethiopia. *Journal of Parasitology Research*, 2020.
16. Gul, R., et al.; Preliminary phytochemical screening, quantitative analysis of alkaloids, and antioxidant activity of crude plant extracts from Ephedra intermedia indigenous to Balochistan. *The Scientific World Journal*, 2017.
17. Gonfa, T., et al.; Effect of extraction solvent on qualitative and quantitative analysis of major phyto-constituents and in-vitro antioxidant activity evaluation of Cadaba rotundifolia Forssk leaf extracts. *Cogent Food & Agricultur*e, **6**(1): p. 1853867, 2020.
18. Mulatu, G.J.A.i.P. and P. Sciences.; Antibacterial activities of Calpurnia aurea against selected animal pathogenic bacterial strains. *Advances in Pharmacological and Pharmaceutical Sciences*, 2020.
19. Luís, Â., et al.; Stumps of Eucalyptus globulus as a source of antioxidant and antimicrobial polyphenols. **19**(10): *Molecules*, p. 16428-16446, 2014.
20. Mekonnen, B., et al.; Antidiarrheal activity of 80% methanolic leaf extract of Justicia schimperiana. *Evidence-Based Complementary and Alternative Medicine*, 2018.
21. Arika, W., et al.; In vivo antidiabetic activity of the aqueous leaf extract of Croton macrostachyus in alloxan induced diabetic mice. **6**(11): p. 1-5, 2015.
22. Mekonnen, N., et al.; Evaluation of berries of Phytolacca dodecandra for growth inhibition of Histoplasma capsulatum var. farciminosum and treatment of cases of epizootic lymphangitis in Ethiopia. *Asian Pacific Journal of Tropical Biomedicine*, **2**(7): p. 505-510, 2012.
23. Tailor, G. and A.J.N.f.E.E. Lawal.; Phytochemical screening; green synthesis, characterization and biological significance of lead oxide nanoparticles from Eucalyptus globulus Labill.(leaves). *Nanotechnology for Environmental Engineering*, **6**(3): p. 1-11, 2021.
24. Ambikar, D., A. Tsegaw, and Y.M.J.J.o.E.P. Belayneh.; Wound Healing Activity of 80% Methanolic Crude Extract and Solvent Fractions of the Leaves of Justicia schimperiana (Hochst. ex Nees) T. Anderson (Acanthaceae) in Mice. *Journal of Experimental Pharmacology*, **14**: p. 167, 2022.
25. Kiristos, T.G., et al.; Phytochemical screening and evaluation of antibacterial activities of Croton macrostachyus stem bark extracts. *Drug Invention Today*, **10**(1): p. 2727-2733, 2018.

26. Belay, D., et al.; Antioxidant and antimicrobial activity of solvent fractions of Calpurnia aurea (Ait.) Benth.(Fabaceae). *Journal of Experimental Pharmacology*, **13**: p. 499, 2021.
27. Bayisa, Y.M. and T.A.J.H. Bullo.; Optimization and characterization of oil extracted from Croton macrostachyus seed for antimicrobial activity using experimental analysis of variance. *Heliyon*, **7**(9): p. e08095, 2021.
28. Umer, S., et al., Antidiarrhoeal and antimicrobial activity of Calpurnia aurea leaf extract. *BMC Complementary and Alternative Medicine*, **13**(1): p. 1-5, 2013.
29. Namulindwa, A., et al.; Determination of the abortifacient activity of the aqueous extract of Phytolacca dodecandra (LHer) leaf in Wistar rats. *Pharmacy and Pharmacology*, **9**(3): p. 43-47, 2015.
30. Pinto, P.C., et al.; Eucalyptus globulus bark as source of tannin extracts for application in leather industry. *ACS Sustainable Chem. Eng.* **1**(8): p. 950-955, 2013.
31. Gizaw, A., et al.; Phytochemical Screening and In Vitro Antifungal Activity of Selected Medicinal Plants against Candida albicans and Aspergillus niger in West Shewa Zone, Ethiopia. *Advances in Pharmacological and Pharmaceutical Sciences*, 2022.
32. Beressa, T.B., et al.; Pharmacology, phytochemistry, and toxicity profiles of Phytolacca dodecandra L'Hér: A scoping review. Infectious Diseases: *Research and Treatment*, **13**: p. 1178633720943509, 2020.
33. Chauhan, P., et al.; In-vitro functional efficacy of extracts from Phyllanthus emblica, Eucalyptus globulus, Tinospora cordifolia as pancreatic lipase inhibitor and source of anti-oxidant in goat meat nuggets. *Food Chemistry*, **348**: p. 129087, 2021.
34. Karpagasundari, C.; S.J.J.o.P. Kulothungan, and Phytochemistry, Analysis of bioactive compounds in Physalis minima leaves using GC MS, HPLC, UV-VIS and FTIR techniques. *Journal of Pharmacognosy and Phytochemistry*, **3**(4): p. 196-201, 2014.
35. Sandt, C., et al.; Use of Fourier-transform infrared spectroscopy for typing of Candida albicans strains isolated in intensive care units. *Journal of Clinical Microbiology*, **41**(3): p. 954-959, 2003.
36. Nurrulhidayah, A., et al.; Application of FTIR spectroscopy coupled with chemometrics for authentication of Nigella sativa seed oil. *Spectroscopy*, **25**(5): p. 243-250, 2011.
37. Paladini, G., et al.; 2D Correlation Spectroscopy (2DCoS) Analysis of Temperature-Dependent FTIR-ATR Spectra in Branched Polyethyleneimine/TEMPO-Oxidized Cellulose Nano-Fiber Xerogels. *Polymers*, **13**(4): p. 528, 2021.
38. Ran, M., et al.; Application of infrared spectroscopy in prediction of asphalt aging time and fatigue life, in Functional Pavements. *Functional Pavements*, p. 45-62, 2020.
39. Liu, C.-C., et al.; Chromium removal and sorption mechanism from aqueous solutions by wine processing waste sludge. *Ind. Eng. Chem. Res.*, **45**(26): p. 8891-8899, 2006.
40. Nostro, A., et al., Extraction methods and bioautography for evaluation of medicinal plant *antimicrobial activity. Letters in Applied Microbiology,* **30**(5): p. 379-384, 2000.
41. Du, Y.-H., et al.; Acaricidal activity of extracts of neem (Azadirachta indica) oil against the larvae of the rabbit mite Sarcoptes scabiei var. cuniculi in vitro. *Veterinary Parasitology*, **157**(1-2): p. 144-148, 2008.
42. Gebrezgabiher, G., et al.; An ethno-veterinary survey of medicinal plants in woredas of Tigray region, Northern Ethiopia. *International Journal of Biodiversity and Conservation,* Vol. **5**(2), pp. 89-97, February, 2013.
43. Zorloni, A., B.L. Penzhorn, and J.N.J.V.p. Eloff,; Extracts of Calpurnia aurea leaves from southern Ethiopia attract and immobilise or kill ticks. *Veterinary parasitology*, **168**(1-2): p. 160-164, 2010.
44. Teklay, A., et al.; An ethnobotanical study of medicinal plants used in Kilte Awulaelo District, Tigray Region of Ethiopia. *Journal of ethnobiology and ethnomedicine*, **9**(1): p. 1-23, 2013.
45. Araya, S., et al.; Study of plants traditionally used in public and animal health management in Seharti Samre District, Southern Tigray, Ethiopia. *Journal of Ethnobiology and Ethnomedicine*, **11**(1): p. 1-25, 2015.
46. Regassa, A.J.J.o.t.S.A.V.A., The use of herbal preparations for tick control in western Ethiopia. *Journal of the South African Veterinary Association*, **71**(4): p. 240-243, 2000.
47. Tolossa, K., et al., Ethno-medicinal study of plants used for treatment of human and livestock ailments by traditional healers in South Omo, Southern Ethiopia. J*ournal of Ethnobiology and Ethnomedicine*, **9**(1): p. 1-15, 2013.
48. Gemechu, W., et al.; An ethno botanical review on medicinal plants used for the management ectoparasitic skin diseases of ruminants.. Journal of Medicinal Plants Studies, **7**(4): p. 212-224, 2019.
49. Tesfaye, H., M. Hishe, and S.J.I.J.o.P. Badasa.; Phytochemical and ethno botanical study of medicinal plants used to treat ectoparasites in ruminant animals in eastern Tigray, northern Ethiopia. *International Journal of Pharmacognosy*, **2**(9): p. 466-472, 2015.
50. Megersa, M., et al.; An ethnobotanical study of medicinal plants in Wayu Tuka district, east Welega zone of oromia regional state, West Ethiopia. *Journal of Ethnobiology and Ethnomedicine*, **9**(1): p. 1-18, 2013.
51. Bekele, D., et al.; Ethnobotanical study of plants used for protection against insect bite and for the treatment of livestock health problems in rural areas of Akaki District, Eastern Shewa, Ethiopia. *Topclass Journal of Herbal Medicine*, Vol. **1**(2) Pp. 40-52, 2012
52. Kabore, A., et al.; Ethno-medicinal study of plants used in ectoparasites infections of ruminant livestock in Sahelian region of Burkina Faso, West Africa. *J. Nat. Prod. Plant Resource*, **2**(5): p. 611-616, 2012.
53. Gemedo-Dalle, T.; B.L. Maass, and J.J.E.b. Isselstein, Plant biodiversity and ethnobotany of Borana pastoralists in southern Oromia, Ethiopia. *Economic botany*, **59**(1): p. 43-65, 2005.
54. Adenubi, O., et al., Plant extracts to control ticks of veterinary and medical importance: A review. *South African Journal of Botany*, **105**: p. 178-193, 2016.
55. Quadros, D.G., et al.; Plant-derived natural compounds for tick pest control in livestock and wildlife: Pragmatism or utopia? *Insects*, **11**(8): p. 490, 2020.

56. Huang, Q., et al., Potential and challenges of tannins as an alternative to in-feed antibiotics for farm animal production. *Animal Nutrition*, 4(2): p. 137-150, 2018.
57. Elango, G., et al.; Efficacy of medicinal plant extracts against Formosan subterranean termite, Coptotermes formosanus. *Industrial Crops and Products*, **36**(1): p. 524-530, 2012.
58. Ghosh, S., et al.; Identification of potential plant extracts for anti-tick activity against acaricide resistant cattle ticks, Rhipicephalus (Boophilus) microplus (Acari: Ixodidae). *Experimental and Applied Acarology*, **66**(1): p. 159-171, 2015.
59. Saxena, M., et al.; Bintaro (Cerbera odollam and Cerbera manghas): an overview of its eco-friendly use, pharmacology, and toxicology. *Environmental Science and Pollution Research*, p. 1-14, 2022.
60. El-Seedi, H.R., et al.; Essential oils of aromatic Egyptian plants repel nymphs of the tick Ixodes ricinus (Acari: Ixodidae). *Experimental and Applied Acarology*, **73**(1): p. 139-157, 2017.
61. Rosado-Aguilar, J., et al.; Plant products and secondary metabolites with acaricide activity against ticks. *Veterinary Parasitology*, **238**: p. 66-76, 2017.
62. De Souza Chagas, A.C., et al.; In vitro efficacy of plant extracts and synthesized substances on Rhipicephalus (Boophilus) microplus (Acari: Ixodidae). *Parasitology Research*, **110**(1): p. 295-303, 2012.
63. K.Sahira Banu, Dr. L.Cathrine.; General Techniques Involved in Phytochemical Analysis. International Journal of Advanced Research in Chemical Science (IJARCS) **2**(4): p. 25-32, 2015

Identification of Gaps in Knowledge and Practices Affecting the Quality of Skins/Hides on the Eve of Eid-Ul-Adha in Pakistan

by

Sadaqat Ali Chattha,[1, 2] Abdul Rehman,[3] Agha Saiddain[4] and Biyu Peng*[1, 5]

[1]*College of Biomass Science and Engineering, Sichuan University,* Chengdu, Sichuan 610065, P.R. China

[2]*Department of Leather & Fibre Technology, University of Veterinary & Animal Sciences*, Lahore, 54000, Pakistan

[3]*Department of Epidemiology & Public Health, University of Veterinary & Animal Sciences*, Lahore, 54000, Pakistan

[4]Environment Society of Pakistan Tanners Association, Lahore, 54000, Pakistan

[5]*National Engineering Laboratory for Clean Technology of Leather Manufacture, Sichuan University*, Chengdu, Sichuan 610065, P.R. China

Abstract

The 2nd largest export-oriented leather industry of Pakistan fulfills its 40% annual raw material demand during the eve of Eid-ul-Adha on which 6.0-8.0 million best-quality animals are being slaughtered within three days. However, a major portion of raw skins and hides (RSH) gets putrefied due to delayed preservation. The aim of this study was to explore the knowledge, attitude, and practices about RSH quality and its preservation in the general public from Punjab, Pakistan. A cross-sectional survey was conducted from February to May 2022 in which 948 individuals from 12 districts participated. Out of six, the overall mean knowledge score of the respondents about RSH preservation was 3.69±1.6 (61.5%). More than half (52.3%) of the respondents answered that salt could be an appropriate option to preserve RSH. However, contrary to their knowledge, only 4.2% (40/948) of respondents applied it correctly. About 56.6% of respondents donated RSH to religious institutes. The mean knowledge and practice scores of the respondents from rural areas were significantly higher ($p<0.001$) than those from urban areas (knowledge: 4.03 vs. 3.13; practice: 4.9 vs. 3.9). The knowledge and practice of preserving RSH using common salt application significantly increased ($p<0.001$) with the level of education (ORs: never attended school = 0.08; school-level education = 0.22 & College/University education = 1.0). In conclusion, almost half of the respondents had knowledge about RSH preservation; however, only a few (4%) practiced it correctly. These findings will be helpful to design effective and targeted interventions to improve the knowledge and practices of the public for better RSH preservation.

Introduction

The leather industry is the 2nd largest export-oriented industry of Pakistan, providing livelihood to more than half a million people and contributing 5.4% to the export earnings of the country[1] with an overall export value of US$ 0.833 billion in 2021.[2] Raw material for the leather industry is well supplied through one of the largest livestock populations in the world comprising nearly 213 million heads. Pakistan is the sixth-largest producer of skins and hides in the world and it is one of the biggest competitive advantages of Pakistan's leather industry.[3]

The raw skins and hides (RSH) supply chain consists of two components. One is the routine slaughtering in which animals are being slaughtered in slaughterhouses/slaughtering slabs; RSH is sold to the RSH collectors; they collect and preserve them and then sell them to big RSH collectors or directly to the tanneries.[4] The second and most important is the eve of Eid-ul-Adha when the bulk of RSH is produced in two to three days. Eid-ul-Adha/Qurbani/Greater Eid is the biggest pious event celebrated by the Muslim community all around the globe on the 10th day of the 12th month (Dhu-al-Hijjah) of the Islamic Lunar Calendar. The skin or hide of the sacrificial animal is directly donated to the welfare/religious organizations[5] or sold to the skin/hide (SH) collector and that money must be donated.[6] About 6.0-8.0 million best quality animals including sheep, goats, cattle, buffalo, and camels are slaughtered annually on this festival and the leather industry fulfills 30-40% of its annual raw material demand from this event.[5,7]

Since the Eid-ul-Adha started to be celebrated during the summer season within the last few years, RSH losses have been increasing year by year, e.g. on Eid-ul-Adha 2020, about 70% of skins/hides (4.2 to 5.4 million) were wasted.[8] This loss is also evident from the leather and leather goods export which dropped from $1.27 to $0.833 billion from 2014 to 2021, respectively.[2] There are multiple factors behind higher RSH loss starting from animal transportation to the slaughtering procedures and storage of skins and hides. Similarly, due to the increasing burden, most of the slaughtering is performed by non-professional butchers leading to more cuts and damage to the RSH.[7] Another malpractice is packing the flayed hides in a plastic bag which is extremely harmful to their quality. For common men, the value of RSH is negligible (less than 1% of an animal value which too must be donated according to religious obligation) and, therefore, there is a lack of interest to preserve the quality. However, from the tanner's point of view, if sacrificial animal hides are not

*Corresponding author: pengbiyu@suc.edu.cn; Tel. +86-28-85401208.

Manuscript received April 25, 2023, accepted for publication June 25, 2023.

preserved within an hour, the hot and humid weather can spoil them to such an extent that no valuable leather article can be produced from them.[9,10]

RSH is composed of 60-70% water and 25-30% protein which is prone to putrefaction within a few hours after its removal from a carcass.[11] This autolytic degradation is believed to be caused by the combined action of tissue enzymes and bacteria however the latter requires moisture for its activity.[12] Bacteria are naturally occupant on the RSH surface as well as in soil/environment and their main roles are to putrefy the RSH collagen protein.[13] The season in which qurbani is being performed in recent years in Pakistan is quite humid (monsoon/rainy) and hot. Therefore, both of these factors add up and cause the start of putrefaction much earlier than the expected time.

The best way to protect skins and hides from bacterial putrefaction is to process them immediately after the slaughtering of animalst.[14] However, this practice is not feasible even in routine slaughtering due to multiple reasons, i.e., busy schedule of tanneries; time required for transportation from the place of slaughtering to a tannery, etc.[15] This option is particularly not feasible on the eve of Eid-ul-Adha where millions of animals are being slaughtered in just three days. The other way which only seems feasible is to preserve or cure RSH with some curing agent. Curing/preservation is a process of creating an environment in which bacteria can't survive.[11] In the literature, several curing agents have been reported e.g., boric acid,[16] potassium chloride,[17] herbal-based products[18] and silica gel.[19,20] However, common salt (sodium chloride, NaCl) is the most practiced and least expensive material used worldwide to cure/preserve RSH, commonly known as wet-salting.[11] In this method, 40-50% NaCl of the green weight of skin/hide is applied immediately after flaying on the flesh side of RSH.[21] It brings about preservation through dehydration and bacteriostatic properties.[22]

Pakistani leather and leather products sector have tremendous potential and growth scope.[23] The skins of Pakistani animals are considered one of the best skins in the world.[24] However, to become more attractive globally, the raw material supply chain especially on the eve of Eid-ul-Adha should be studied more comprehensively. The big fraction of skins and hides which get wasted every year worth of billions of Pakistani rupees (PKR) can be saved through proper management and vision. Therefore, this study was conducted to assess the knowledge, attitudes, and practices of the common man regarding RSH preservation through common salt application and to identify the important loopholes in the preservation process. To the best of our knowledge, this is the first study in Pakistan, and we are very optimistic that the findings of this study will help to formulate more targeted interventions to better preserve RSH on the eve of Eid-ul-Adha leading to better economic growth.

Methodology

Study area and data collection

The study focused on the Punjab province which holds more than 50% of the total human and animal population of the country. Out of 36 districts of the Punjab, 12 districts were selected randomly. To assess the knowledge, attitude, and practices (KAP) of the general public about RSH preservation, a questionnaire was developed in consultation with the relevant experts, reviewing published literature and after multiple discussions with the stakeholders/collectors. The data was collected from 948 respondents who were involved in slaughtering at the eve of Eid-ul-Adha between February and May 2022. The survey comprised of three sections: 1) Demographic information of the participants (6 questions), 2) Knowledge about RSH preservation (6 questions), 3) Attitude towards correct practices regarding RSH preservation and Practices of participants about RSH preservation on the eve of Edi-ul-Adha (12 questions). Including the demographic data, the final questionnaire comprised 24 questions of which four were open-ended and 20 close-ended questions. The English version of the questionnaire was translated into Urdu (local language). Formal testing of the questionnaire was performed with 40 respondents in urban and rural areas prior to launching the final survey. An information sheet containing the details of the study was presented to the participants before obtaining consent from them and the data was kept strictly confidential by removing the personal identifier. The average time per interview was about 25 minutes.

Data analysis

The data were analyzed using R software 4.0.4 and RStudio version 1.4.1106 as an interface (R Core Team, 2021; RStudio Team, 2021). KAP scores were calculated by combining scores of respondents in each category, i.e. correct answers in knowledge questions, attitude questions, and practice questions. Each correct answer was given 1 and the incorrect answer was given 0. For continuous variables, i.e. knowledge, attitude, and practice scores, means were presented, and data related to demographic variables were presented as proportions and frequencies. Linear regression models were built to find out the association of demographic factors with mean knowledge, attitude, and practice scores using *lm* function. We identified three important practices that could affect RSH preservation; 1) putting the hair side of the skin inwards and the meat side outwards after flaying, 2) putting RSH in a plastic bag, and 3) application of common salt. The effect of demographic factors on identified practices was assessed using univariable analysis followed by a multivariable logistic regression model using *glm* function separately for each identified practice. Univariable analysis was performed using Pearson Chi-squared test and only those variables which yielded $p<0.2$ were further considered for the multivariable logistic regression model. The non-significant

Table I

Description of questions included in KAP survey along with correct and incorrect answers

Question	Correct options	Incorrect options
Methods to keep the quality of sacrificial RSH good	Salt application	Putting under shade.
		Putting in direct sunlight.
		Putting in a plastic bag.
		Putting in a plastic bag + putting under shade.
		Putting in a plastic bag + putting in direct sunlight.
How the skin of the sacrificial animal should be kept after slaughtering& flaying?	Inner side outwards and hair side inwards	Hair side outwards and inner side inwards
How does leftover meat affect the quality of RSH	Reduces Quality	Improves quality
Putting RSH in a plastic bag is good or bad	Bad	Good
How many hours after flaying salt should be applied in summer season	Immediately	Within 8 hours
		Within 24 hours
Who did slaughtering & flaying	Professional butcher	Untrained butcher
	Slaughterhouse	Own self
After flaying, where RSH was kept	Under shade	Under direct sun light
		In a water tub full of chilled water
How many hours after flaying, RSH was handed over to collector	0.5-01 hr	02-03 hrs
		04-05 hrs
		06-07 hrs
		More than 08 hrs
Which method was adopted to keep RSH quality good before handing it over to collector	Application of common salt.	Sprinkling of chilled water.
	Application of common slat & boric acid	Skin was handed over as it is
After how many hours of flaying, common salt was applied	0.5-01 hr	02-03 hrs
		04-05 hrs
		06-07 hrs
		More than 08 hrs
		Not applicable/Didn’t apply salt
Quantity of salt used to preserve sheep & goat skin	01-02 kg	03-04 kg
	Not Applicable	
Quantity of salt used to preserve cow & buffalo hides	03-05 kg	06-08 kg
	Not Applicable	

variables and/or confounders (assessed at 20% change in the estimates of the remaining variables) were stepwise removed using a backward selection approach. The *sjPlot* package was used to take the final output of the model containing odds ratio, p-value and R^2. Odds ratios along with 95% confidence intervals (CI) are presented only for the significant variables in the multivariable model. The R^2 values were used to assess the model fit.

Ethical Approval

The study was approved by the Ethical Review Committee of the University of Veterinary and Animal Sciences, Lahore (No. DR/687).

Results

Demographic characteristics of the respondents

Out of 948 respondents, 40.1% performed slaughtering in urban areas, while 59.9%in rural settings. The majority of the respondents either got school level (47.5%) or college/university level (46.6%) education, while a small proportion (5.9%) had not received any formal education. Similarly, general data about the source of getting information concerning the importance of RSH and its preservation process; the type of an animal slaughtered on the eve of Eid-ul-Adha; to whom RSH was donated/sold, and the willingness of participants to slaughter their animals if the government makes some arrangement for a combined slaughtering of animals in their area on nominal rates, has been presented in Table II.

Respondents' Knowledge

The majority of the respondents (66.9%) were well aware that any cut (flaying cut) during the skin removal (flaying) could influence its quality; however, 33.1% believed that flaying cuts had no influence on the quality of skin (Table II). Similarly, 79.6% were well cognisant that the leftover meat reduces the quality of RSH. The correct preservation method of RSH was correctly identified by 52.3% of respondents. Responding to the question of when salt should be applied after flaying, particularly in the summer season, less than half of the respondents (46.1%) were able to answer it correctly. Similarly, when they were asked whether it is good or bad to keep/put the skins in a plastic bag after slaughtering, 63.2% and 36.8% picked the "bad" and "good" options, respectively. One very important parameter that how the skin of the sacrificial animal should be kept after slaughtering; only 39.1% of the respondents were able to answer correctly.

Respondents' Attitudes and Practices

Only 58.9% of the respondents performed the antemortem examination. Almost half (49.8%) of the respondents strictly instructed butchers to do flaying with care. The majority of the respondents (55%) slaughtered their animals themselves or obtained services from untrained butchers, while 45% respondents hired professional butchers for slaughtering. After flaying, the majority (63.1%) of the respondents kept skins incorrectly (hair side outwards and meat side inwards) while 36.9% of them, correctly. Similarly, majority of the respondents (66.8%) kept the skins under shade and the rest of the respondents kept RSH either in direct sunlight (31.1%) or in a water tub full of chilled water (2.1%). About 40.1% of the respondents reported that they placed the skins in plastic bags. About 43% of the respondents applied common salt or common salt + boric acid to preserve RSH before handing it over to the collector and the rest of the respondents either handed it over as it is (52.8%) or sprinkled chilled water (4.1%) to keep its quality good. Of those who applied salt or salt + boric acid (n=408) for RSH preservation before handing it over to the receiver (collector, religious/welfare organizations, etc.), the majority either delayed the salt application (54.7%), applied salt on the wrong side of RSH (77.5%), did not remove leftover meat before salt application (86%), applied inappropriate quantity of salt (86.8%) or placed RSH in a plastic bag or in direct sunlight after salt application (90.2%). Thus, only a small proportion of the respondents 4.2% (40/948) applied salt appropriately (Table II).

Association of demographic factors with knowledge and preservation practices

Out of six, the overall mean knowledge score of the respondents was 3.69±1.6. The mean knowledge score of the respondents from the rural area was significantly higher than those from the urban area (4.03 vs. 3.13, $p<0.001$). The mean knowledge score of respondents who never went to school (3.29±1.39) or received school-level education (3.5±1.61) was found significantly lower ($p<0.001$) than those who attended college/university (3.94±1.58).

Out of total practice score (12), the overall mean score of the respondents was 4.53. The mean practice score of the respondents from the rural area was significantly ($p<0.001$) higher than those from the urban areas (4.9 vs. 3.9). Similarly, the mean practice score of respondents who never attended school or received primary education was found significantly ($p<0.001$) lower (3.03 & 3.94, respectively) than those with college/university education status (5.32).

Table II

Demographic characteristics of respondents, general questions, and responses to questions related to knowledge, attitude, and practices about raw skins/hides preservation

Variable	Level	Responses	%
Demographic			
Area	Rural	568	59.9
	Urban	380	40.1
Education level	Never went to school	56	5.9
	School	450	47.5
	University/college	442	46.6
General Questions			
Source of getting information about the importance of RSH and its preservation process	Social media	301	31.8
	Religious/welfare organizations campaigns	154	16.3
	Announcement from nearby mosque	95	10.0
	Electronic media	60	6.3
	Newspaper	24	2.5
	Did not receive any information from any source	314	33.1
Type of animal slaughtered on Eid-ul-Adha	Cow	347	36.6
	Buffalo	128	13.5
	Camel	11	1.2
	Goat	357	37.6
	Sheep	105	11.1
To whom RSH was donated	Religious institutes	537	56.6
	Welfare organizations	141	14.9
	Poor men	93	9.8
	Butchers	51	5.3
	Sold to RSH collectors	63	6.7
	Buried into the earth	15	1.6
	Don't know	48	5.1
If the government makes some arrangements for a combined slaughtering of animals in your area at nominal rates, would you prefer to use this facility?	Yes	301	31.7
	No	268	28.3
	Depends upon the distance from home	379	40
Knowledge			
Flaying cuts affect the price of the RSH	Yes	634	66.9
	No	314	33.1
Methods to keep the quality of sacrificial RSH good	Salt application	496	52.3
	Putting under shade	203	21.4
	Putting in direct sunlight	66	7.0
	Putting in a plastic bag	71	7.5
	Putting in a plastic bag + putting under shade	34	3.6
	Putting in a plastic bag + putting in direct sunlight	78	8.2
Putting RSH in a plastic bag is good or bad	Good	349	36.8
	Bad	599	63.2
How the skin of the sacrificial animal should be kept after slaughtering& flaying?	Inner side outwards and hair side inwards	371	39.1
	Hair side outwards and inner side inwards	577	60.9
How does leftover meat affect the quality of RSH?	Improves quality	193	20.4
	Reduces Quality	755	79.6
How many hours after flaying salt should be applied in summer season?	Immediately	437	46.1
	Within 8.0 hours	277	29.2
	Within 24.0 hours	234	24.7

Variable	Level	Responses	%
Attitude & Practices			
Did you observe the physical appearance of the skin before slaughtering?	Yes	558	58.9
	No	390	41.1
Who did slaughtering & flaying?	Professional butcher	414	43.7
	Untrained butcher	112	11.8
	Slaughterhouse	12	1.3
	Own self	410	43.2
Had butcher/own self been instructed/reminded to avoid flay cuts?	Yes	472	49.8
	No	476	50.2
After flaying, how RSH was kept	Meat side outwards and hair side inwards	350	36.9
	Hair side outwards and meat side inwards	598	63.1
After flaying, where RSH was kept	Under direct sun light	295	31.1
	Under shade	633	66.8
	In a water tub full of chilled water	20	2.1
Did you put the RSH in a plastic bag after flaying?	Yes	380	40.1
	No	568	59.9
How many hours after flaying, RSH was handed over to the collector?	0.5-1.0 hr	136	14.3
	2.0-3.0 hrs	304	32.1
	4.0-5.0 hrs	202	21.3
	6.0-7.0 hrs	177	18.7
	More than 8.0 hrs	129	13.6
Which method was adopted to keep RSH quality good before handing it over to the collector?	Application of common salt	389	41.0
	Application of common slat & boric acid	19	2.0
	Sprinkling of chilled water	39	4.1
	RSH was handed over as it is	501	52.9
After how many hours of flaying, common salt was applied	0.5-01 hr	185	19.5
	02-03 hrs	117	12.3
	04-05 hrs	39	4.1
	06-07 hrs	44	4.6
	More than 08 hrs	23	2.4
	Not applicable/Didn't apply salt	540	57.1
Quantity of salt used to preserve sheep & goat skin	01-02 kg	158/462	34.2
	03-04 kg	42/462	9.1
	Not applicable	262/462	56.7
Quantity of salt used to preserve cow & buffalo hides	03-05 kg	151/486	31.1
	06-08 kg	57/486	11.7
	Not applicable	278/486	57.2
Did the leftover meat remove before salt application	Yes	196/408	48.0
	No	212/408	52.0
Number of respondents who applied salt within an appropriate time limit, location, technique, quantity, and method			
No. of respondents practiced RSH preservation through the salt application (common salt or common salt+boric acid).		408	43.0
No. of respondents applied salt within an appropriate time limit (0.5-01 hr).		185	19.5
No. of respondents applied salt in the appropriate location (on the meat side of the RSH).		92	9.70
No. of respondents applied salt through an appropriate technique (removed leftover meat before salt application).		57	6.0
No. of respondents applied the appropriate quantity of salt (1-2 kg for goat/sheep; 3-5 kg for cow/buffalo).		54	5.7
No. of respondents who kept RSH in an appropriate way (did not place RSH in a plastic bag or in direct sunlight after salt application).		40	4.2

Table III

Linear regression model to find out the association of education and locality with knowledge and practice about RSH preservation

Variable	Predictor	Estimates	CI	P-value
KSUM	Intercept	3.39	3.20 – 3.57	<0.001
	Area (Rural)	0.91	0.71 – 1.11	<0.001
	Education level (Never went to school)	-0.71	-1.13 – -0.28	0.001
	Education level (School)	-0.47	-0.67 – -0.27	<0.001
PSUM	Intercept	4.67	4.39 – 4.96	<0.001
	Area (Rural)	1.06	0.75 – 1.37	<0.001
	Education level (Never went to school)	-2.34	-2.99 – -1.69	<0.001
	Education level (School)	-1.41	-1.72 – -1.10	<0.001

Association of demographic characteristics with identified practices

The practice of putting the hair side of the skin inwards and the meat side outwards after flaying was significantly less ($p<0.001$, OR = 0.73) in rural areas than those in urban areas (Table IV). Similarly, this practice was found five times less ($p<0.001$; OR = 0.21 & 0.65) among respondents who never went to school and two times less among those who received school-level education compared to those who attended college/university. The other important practice of putting RSH in a plastic bag was three times higher ($p<0.001$; OR = 2.76) among respondents from rural areas compared to urban areas. Another important practice of common salt application was found significantly more common (OR = 2.31, $p<0.001$) in the respondents from rural areas compared to the urban areas. Similarly, this practice was significantly ($p<0.001$) less in respondents who never went to school (OR = 0.08) or had school-level (primary) education (OR = 0.22) as compared to those who received college/university-level education.

Table IV

Summary of multivariable logistic regression model to find out the association of education and locality with identified practices

Variable	Predictor	Odds ratio	95% CI	P-value
Skin inwards	Urban	1.00	-	-
	Rural	0.73	0.56 – 0.96	0.026
	College/University-level education	1.00	-	-
	Never went to school	0.21	0.09 – 0.43	<0.001
	School-level education	0.65	0.49 – 0.85	0.002
Plastic bag utilization	Urban	1.00	0.67 – 1.02	0.080
	Rural	2.76	2.11 – 3.64	<0.001
Application of common salt	Urban	1.00	-	-
	Rural	2.31	1.72 – 3.12	<0.001
	College/University-level education	1.00	-	-
	Never went to school	0.08	0.03 – 0.17	<0.001
	School-level education	0.22	0.17 – 0.30	<0.001

Discussion

Knowledge related to RSH preservation

This is the first study to identify the knowledge, attitude and practices of the Pakistani population regarding RSH handling and preservation on the eve of Eid-ul-Adha. This result may reflect the situation that there is a lack of systemic interventions in respondent's knowledge of RSH preservation. Overall, the knowledge of the respondents from urban areas was found to be lower than that of rural areas. It could be due to the fact that in Pakistan; most of the people living in cities go to their native rural areas to celebrate this eve with their loved ones.[7,25] So, this urban population does not truly mean it. The least knowledge about RSH preservation and its quality safeguarding was found in the respondents with never went to school education status and highest among those with college/university education status. However no significant difference of knowledge was found between the never went to school and school education status. This could be due to the access to print, electronic and particularly social media to the participants with higher education status.

Attitude and practices related to RSH preservation

A comprehensive review of the slaughtering procedure on the eve of Eid-ul-Adha is mandatory for a better understanding of the mega wastage of RSH during this event. Basically, the slaughtering of animals at Eid-ul-Adha is performed in two ways, individual slaughtering and combined slaughtering (Figure 1). In both types of slaughtering, the animal is purchased either directly from a farmer, temporary livestock market (especially established by a local government for two to three weeks before Eid-ul-Adha around the cities to facilitate the public) or permanent livestock markets (exists throughout the year around the cities).[7,26,27]

In both types of slaughtering systems, one commonality is that flaying is almost always done by hand, therefore, RSH contains a greater number of flaying cuts. Even in combined slaughtering (10-20 animals are slaughtered at a single and open place) slaughtering is performed by professional and amateur butchers,[7] flaying cuts also prevail here too, because these butchers are always in a hurry to slaughter more animals per day to make more money. After flaying, most of the time people focus on getting meat as soon as possible because they have to cook it for a family lunch or distribute it among friends/needy people, so they intentionally ignore preserving it with salt.

Overall, 43% (408/948) of respondents preserved RSH through common salt or common salt+boric acid application. However, out of this, the percentage of respondents who applied salt correctly

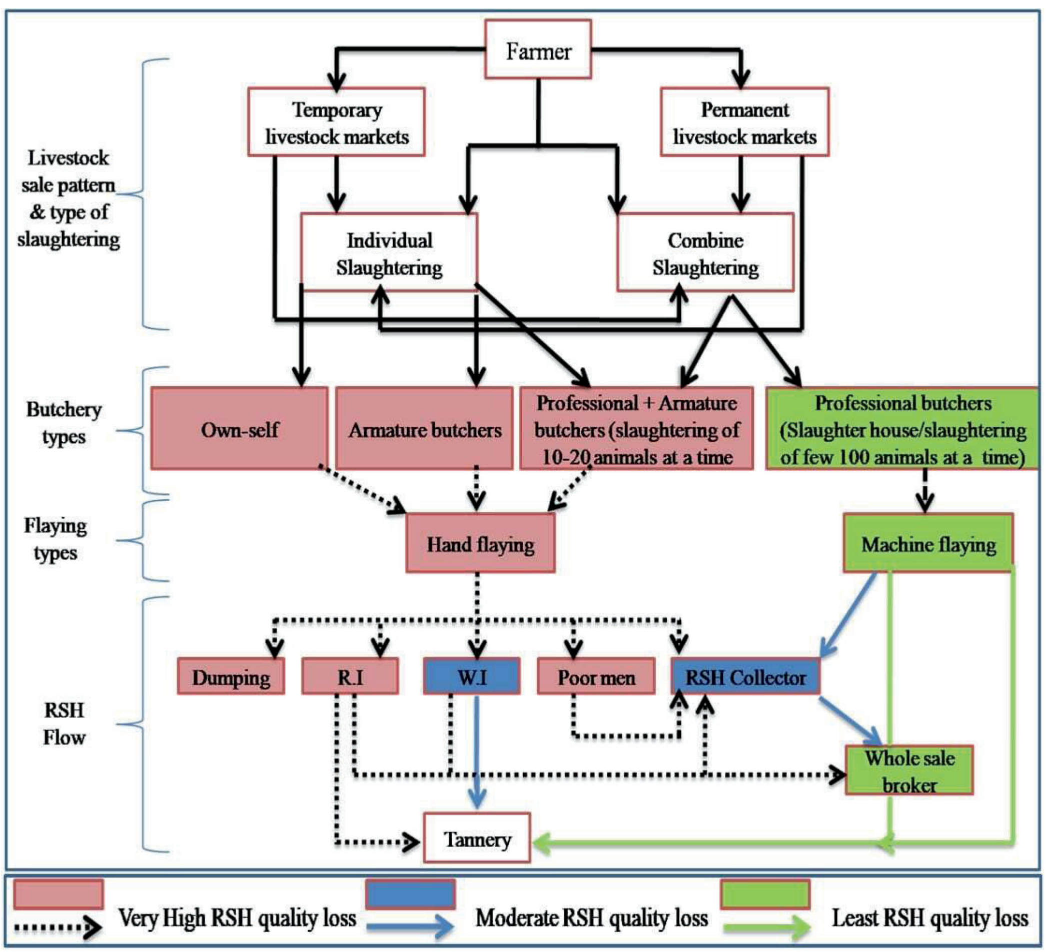


Figure 1. Livestock sale pattern; types of slaughtering; butchery types; flaying types and RSH flow on the eve of Eid-ul-Adha in Pakistan. Source: Own illustration based (RI= Religious institutes; WI= Welfare institutes)

was incredibly low. Only 4.2% (40/948) respondents had applied salt correctly i.e. within an appropriate time limit (0.5- 1.0 hr), on correct side of the RSH, after removing the leftover meat, sufficient salt quantity and placing RSH under a shade. There could be multiple reasons behind this fact but the major one is evident from the comments of the respondents. They reported that a few years ago, the price of small and large skins was quite high which has been much reduced now. Then why should they apply salt and waste their money? Why shouldn't they donate it as such or dump it into the earth? They also emphasized that the government should increase the price of RSH. Therefore, due to the lower price of RSH, common men are not well interested to apply salt because for them the RSH is nothing except a liability. A few years ago; the price of Eid-ul-Adha skins and hides was really good because at that time this festival was celebrated in the winter season and overall temperature in those months was not quite high and RSH did not putrefy so quickly. However, the temperature and humidity in the current as well in an upcoming couple of years would be quite high and the proportional risk of RSH putrefaction would be very high without salt application. Secondly, people are not well aware of the importance of timely salt application, and only 19.5% (185/948) applied salt within an appropriate time limit (0.5-1.0 hr). Similar findings have also been reported from Bangladesh on the eve of Eid-ul-Adha where the public is also not aware of applying salt timely rather it is considered as the duty of tanneries and RSH collectors.[28]

Thirdly, it is very important to know how to keep the skin after flaying. The meat side of RSH should always be kept outwards and the hair side inwards and salt is always applied on the meat side, however, only 9.7% (92/948) of respondents applied salt on the correct side. Fourthly, removing leftover meat and fat from RSH before salt application is also important for its proper preservation but only 6% (57/948) did this practice in the correct way. Five, the correct quantity of salt application is also very important to preserve RSH from putrefaction but only 5.70% (54/948) did it in the correct way. Similarly, after salt application, it's important to keep RSH under shade and in a well-ventilated place without putting it in a plastic bag. Keeping/putting RSH in a plastic bag increases the temperature which in turn facilitates bacterial growth and thus speeds up the putrefaction process. It is a very bad practice prevailing in the public and more than one-third (40.08%) of respondents put RSH in a plastic bag (either at the home level or used as a means of transportation from home to a collection/donation center). All the aforementioned factors contributed significantly to producing an overall score of 4.2%.

We also have identified some very important individual practices which are being practiced differently by rural and urban populations and education status. The practice of putting the hair side of the skin inwards and the meat side outwards after flaying in the respondents from rural areas was observed significantly lower than those from urban areas. Similarly, this practice was found significantly less in the respondents with never went to school and school education status as compared to those with college/university education status (Table IV). It means the urban population with higher education status is more adapted in this practice. The major reason could be the higher awareness (through social/electronic/print media) or due to higher income and affordability, most of the urban respondents could have hired professional butchers for slaughtering and flaying. The other important practice of putting RSH in plastic bags was found significantly less in the respondents from rural areas as compared to urban area respondents. If three respondents from the urban side were putting RSH in plastic bags, then only one respondent from the rural area was doing the same practice. Education status did not affect this practice significantly. The possible reason could be less availability of plastic bags in the rural areas as fertilizer empty bags are excessively available in the rural areas so they might have placed RSH in those bags instead of plastic bags while handing over RSH to the collector. The next very important practice, salt application, was found significantly more in the respondents from the rural areas as compared to the urban area. However, this practice was significantly found less in the respondents with never went to school and school education as compared to college/university education status. Both types of respondents, never went to school and school education status, had also a significant difference with each other in this practice. The possible reason could be the rural background of most of the respondents from urban areas who, although residing in urban areas, have performed slaughtering in their native rural areas. The education level had a significant effect on the said practice which implies that by improving the education/knowledge of the population their practice of salt application could be improved.

Based on the results of this study, we have made some calculations to know the economic impact of RSH wastage. According to the available literature, about 6.0-8.0 million animals are slaughtered on this eve. In this calculation, we have assumed an average price of a well-preserved and well-flayed RSH according to the available market rate. As is evident from Table V, every year Pakistan is bearing a loss worth of PKR 17,211.9 million. To save all these RSH, Pakistan needs to spend 952.9 million PKR/annum (Table VI) and as a result can save PKR 16,258.7 million per annum.

Conclusion

About half of the respondents knew about the skin/hide preservation method, however, the majority did not practice it correctly. The incorrect practices include delayed salt application (54.7%), applying salt on the wrong side (77.5%), did not remove leftover meat before salt

Table V

Per annum loss (million PKR) due to RSH wastage on the eve of Eid-ul-Adha

RSH type & percentage	Production	RSH lost (95%)	Avg. price/RSH	Total Loss (Million PKR)
Cow hides (36.6%)	2,562,700	2,434,565	3,000	7,303.7
Buffalo hides (13.5%)	942,200	895,090	4,000	3,580.4
Camel (1.2%)	84,000	79,800	1,500	119.7
Goat (37.6%)	2,630,600	2,499,070	400	999.6
Sheep (11.1%)	780,500	741,475	200	148.3
Annual import of RSH	0.00	0.00	0.00	5,060
			Total	17,211.7

Table VI

Per annum estimated expense (million PKR) to save RSH on the eve of Eid-ul-Adha

RSH type	No. of RSH	Salt req. to save one RSH (kg)	Avg. price of salt (PKR/kg)	salt cost (PKR)	Total cost of salt (million PKR)
Cow	2,434,565	5	15	75	182.6
Buffalo	895,090	5	15	75	67.1
Camel	79,800	5	15	75	6
Goat	2,499,070	2	15	30	75
Sheep	741,475	2	15	30	22.2
Awareness campaign cost	N/A	N/A	N/A	N/A	600
				Total	952.9

application (86%), applying inappropriate quantity of salt (86.8%), or placed skin/hide(s) in a plastic bag or under direct sunlight (90.2%). Thus, only a small proportion of the respondents, 4.22% (40 out of 948), preserved skins/hides using the correct method. Hence, the government, Pakistan Tanners' Association (PTA) and related non-government organizations need to pay more focus on mobilizing the RSH preservation campaign through salt application on social media by hiring some professionals. It could be a more effective way as the majority (31.75%) of the respondents got information through this channel. The other effective and cheaper way could be initiating awareness campaigns through religious/welfare organizations or Friday religious sermons close to Eid-ul-Adha in mosques. In addition, our findings can also be used to design more effective and targeted interventions to improve the knowledge and practices of the general public and as baseline data for monitoring future interventions.

Acknowledgements

The authors are highly grateful to the local veterinarians working in the respective districts, Pakistan Tanners Association, and skin & hide collectors from the respective districts for their untiring support in questionnaire improvement and data collection. We are thankful to the Chinese Government for providing a scholarship under the One Road and One Belt Initiative to Mr. Sadaqat for the completion of his Ph.D. studies.

References

1. Bushra, S., Khalil, P. S and Ali, S. A.; Measuring undesirable output in efficiency evaluation: the case of tanneries in Pakistan. *PalArch's J Archaeol Egypt/Egyptology* **18**, 392–413, 2021.
2. Zafar, S., Tayyab, M and Salam, A.; Pakkistan tanners association annual report, pp 5-13, 2021. https://www.pakistantanners.org/documents/annualreport2021.pdf

3. Shah, T., Zafar, S., Muslim, E., et al.; Pakistan Export Strategy 2023-2027: Leather and Leather Goods. International Trade Center Geneva, Switzerland, pp: 1-101, 2022. https://tdap.gov.pk/wp-content/uploads/2022/08/Leather-and-Leather-Goods-Export-Strategy-4_web.pdf
4. Khaskheli, A. A.; Skin and Hides Selling Practices at Coastal Area of Sindh Province of Pakistan. *Biomed J Sci Tech Res* **30**, 23401–8, 2020.
5. Nawaz, M., Yousafzai, M. T., Khan, S. et al.; Assessing the formal and informal waste recycling business processes through a stakeholders lens in Pakistan. *Sustainability* **13**, 11717, 2021.
6. Saeed, A.; A fourth of Eid animal hides in Pakistan spoil due to poor processing-tanning association. https://arab.news/c5bn6
7. Mallhi, T. H., Khan, Y. H., Alotaibi, N. H. et al.; Celebrating Eid-ul-Adha in the era of the COVID-19 pandemic in Pakistan: potential threats and precautionary measures. *Clin Microbiol Infect* **26**, 1714–5, 2020.
8. UVAS.; Hide saltation Eid-ul-Adha by UVAS Dept. of leather & fiber technology, 2021. https://www.youtube.com/watch?v=He-w4-HSuqM
9. Fizza, I.; Processing of animal hides begins at tanneries. https://www.dawn.com/news/1210907
10. Jabri, P.; Lack of awareness damages hides worth Rs. 1.5 bn on Eid –ul-Azha: PTA. https://www.brecorder.com/news/367495.
11. Hernandez, E., Marmer, W., Kolomaznik, K., Cooke, P., & Dudley, R.; Mathematical model of raw hide curing with brine. *JALCA* 103, 167-173, 2008.
12. Rao, B. R., & Henrickson, R. L.; Preservation of hides with soda ash. *JALCA* 78, 48-53, 1983.
13. Vijayalakshmi, K., Judith, R and Rajakumar, S.; Novel plant based formulations for short term preservation of animal skins. *J Sci Ind Res* **68**, 699–707, 2009.
14. Bayramoğlu, E. E., Yilmaz, S and Çivi, S.; World raw hide and skin exports and some microbiological problems during exportation. In: International Conference on Advanced Materials and Systems (ICAMS) The National Research & Development Institute for Textiles and Leather-INCDTP, pp. 403–7, 2018.
15. Nur-A-Tomal, M. Sand Hashem, M. A.; A novel method to preserve goat skin with indigenous plant extract to reduce salinity in the effluent. In: In International Union of Leather Technologists and Chemists Congress 2017 CSIR-CLRI, pp. 46–55, 2017.
16. Kanagaraj, J., John, S. V., Muralidharan, C. et al.; Alternatives to sodium chloride in prevention of skin protein degradation—a case study. *J Clean Prod* **13**, 825–31, 2013
17. Bailey, D. G., & Gosselin, J. A.; The preservation of animal hides and skins with potassium chloride. *JALCA* 91, 317-333, 1996.
18. Preethi, V., Rathinasamy, V., Kannan, N., Babu, C., & Sehgal, P. K.; Azardirachta indica: a green material for curing of hides and skins in leather processing. *JALCA* 101, 266-273, 2006.
19. Kanagaraj, J., Chandra, B. K., Sadulla, S. et al.; Cleaner techniques for the preservation of raw goat skins. *J Clean Prod* **9**, 261–8, 2001
20. Munz, K.; Silicates for raw hide curing. *JALCA* 102, 16-21, 2007.
21. Vankar, P. S and Dwivedi, A. K.; Raw skin preservation through sodium salts—a comparative analysis. *Desaltation* **249**, 158–62, 2009.
22. Babu, T, G., Nithyanand, P., Babu, N. K. et al.; Evaluation of cetyltrimethylammonium bromide as a potential short-term preservative agent for stripped goat skin. *World J Microbiol Biotechnol* **25**, 901–7, 2009.
23. Shahab, S and Mahmood, M. T.; Comparative advantage of leather industry in Pakistan with selected Asian economies. *Int J Econ Financ Issues* **3**, 133–9, 2013.
24. Ghafoor, A., Aslam, M and Rasool, S.; Determinants of Leather Goods Exports : A Case of Pakistan. *J Bus Econ* **4**, . 2012;4(2):256–69.
25. Rahman, F. N., Rahman, A. F., Iwuagwu, A. O. et al.; COVID-19 Transmission due to mass mobility before and after the largest festival in Bangladesh: An Epidemiologic Study. *J Heal Care Organ Provision Financ* **58**, 00469580211023464, 2021.
26. Atif, M., Saqib, A., Ikram, R. et al.; The reasons why Pakistan might be at high risk of Crimean Congo haemorrhagic fever epidemic; a scoping review of the literature. *Virol journal* **14**, 1–7, 2017.
27. Mallhi, T. H., Khan, Y. H., Tanveer, N. et al.; Commentary: surveillance of Crimean-Congo haemorrhagic fever in Pakistan. *Front public Heal* **5**, 132, 2017.
28. Strasser, J., Dannenberg, P and Kulke, E.; Temporary resource availability and quality constraints in the global leather value chain - The impact of the festival of sacrifice on the leather industry in Bangladesh. *Appl Geogr* **45**, 410–419, 2013.

Experimental and Computational Fluid Dynamics Investigation on Tanning Process in a Rotating Drum

by
Yirui Lin,[1] Zhuocheng Jiang,[2] Ya-nan Wang,[1,3] Yunhang Zeng,[1,3]* Guo Xie[2]*and Bi Shi[1,3]
[1]*National Engineering Laboratory for Clean Technology of Leather Manufacture, Sichuan University,* Chengdu 610065, China
[2]*State Key Laboratory of Hydraulics and Mountain River Engineering, College of Water Resource & Hydropower,* Sichuan University, Chengdu 610065, China
[3]*Key Laboratory of Leather Chemistry and Engineering (Sichuan University), Ministry of Education,* Chengdu 610065, China

Abstract

Mass transfer of chemicals greatly affects leather production efficiency and product quality. Leather shows different motions in a rotating drum during processing, which is strongly associated with chemicals' mass transfer. However, how leather motions affect mass transfer remains unclear, which disfavors highly efficient leather manufacturing process. Here, different leather motion states were obtained by adjusting the drum rotation speed. Experimental results showed that the duration of leather rolling motion greatly increased by 41% when the rotation speed increased from 5 r/min to 20 r/min, and the uptake of the tanning agent was consequently improved, which indicated that the rolling motion is beneficial to mass transfer. Computational fluid dynamics simulation results showed that the mass transfer rate under rolling motion was higher than those under slipping, elevating and hanging motions, because the flow velocity and concentration gradient near the leather surface were higher under rolling motion. Accordingly, increasing the rolling motion enhanced the mass transfer in leather processing. This work identifies the leather motion beneficial for mass transfer and provides guidance on operating condition optimization and drum design for high-efficiency leather production.

Introduction

Leather manufacturing converts animal hides/skins, the by-products of the meat industry, into valuable leather products, which offers important economic benefits and reduces the waste of natural resources.[1] The leather making process is divided into four stages: beamhouse, tanning, post-tanning and finishing.[2] In the first three stages, hides/skins are processed in a rotating drum with various chemicals, involving surfactant, sodium sulfide, lime, ammonium sulphate, enzyme, acid, basic chromium sulphate, acrylic resin, vegetable tannin, and dyestuff [Figure 1(a)].[3] These chemicals react with hide collagen fibers which are the vital components of leather and endow the leather with satisfactory properties (i.e. hydrothermal stability, resistance to bacteria/enzymes, flexibility, comfortable feel, beautiful colors).[4] However, the transfer of chemicals into hides/skins is greatly resisted by the complicated porous fiber network of hides/skins.[5,6] Further, the chemicals are prone to combine with collagen fibers on the hide surface through covalent bonding, coordination, electrostatic interaction, hydrogen bonding, van der Waals interaction or hydrophobic interaction, which negatively affects the transfer of chemicals to the inner hide [Figure 1(a)].[7] Rapid penetration and uniform distribution of chemicals in leather play an important role in the quality and production efficiency of leather. For example, tanning agents that can make hides resistant to thermal shrinkage and bacteria/enzymes are considered the most important chemicals for leather making. However, they are easily deposited on the hide surface through chemical interactions, which leads to the rough surface and low hydrothermal stability of leather. Therefore, the mass transfer enhancement of chemicals has received much attention for producing high-quality leather.

Extensive research has shown that the most important factors influencing the solid–liquid mass transfer process are interfacial turbulence,[8-10] two-phase contact area,[11] the diffusion rate of components[12] and the properties of solids and liquids.[13,14] In the leather industry, many attempts have been made to enhance the mass transfer of chemicals in hides/skins, such as adjusting the surface charge of hides/skins,[15-17] the properties of chemicals (charge, functional groups and molecular weights)[18-21] and the amount or properties of liquid (dielectric constant, density and chemical bond)[22,23] in the drum. These attempts show promising potential for the rapid penetration and high uptake of chemicals. Notably, the mechanical actions of the drum (rolling, collision, extrusion and pulling) also greatly affect the mass transfer of chemicals in leather. In fact, tanners have found that optimizing the operating conditions (rotation speed, loading quantity, the ratio of leather to float) and drum structure is an efficient way to improve the mass transfer of chemicals and is even superior to the above methods.[24-26] However, the operating drum conditions are often determined by the experience of tanners rather than scientific theory. In the rotating drum, the leather shows various motion characteristics, including velocities and motion states [Figure 1(b)], which bring about the variation of interfacial turbulence and

*Corresponding authors email: zengyunhang@scu.edu.cn (Y . H. Zeng), 2008xieguo@scu.edu.cn (G. Xie)
Manuscript received April 17, 2023, accepted for publication June 25, 2023.

the contact area between leather and float. Previous studies have focused on the chemical reactions between leather and chemicals, but little attention has been paid to how to optimize the drum mechanical actions and the motion characteristics of leather. Hence, the quantitative relationship between leather motion characteristics and the mass transfer of chemicals remains unclear. Undoubtedly, this knowledge gap hinders scientific guidance in the adjustment of drum mechanical actions and the mass transfer enhancement of leather chemicals.

Computational fluid dynamics (CFD) simulation is a powerful method for investigating the mass transfer process in a rotating flow field. Santos et al. studied the particle dynamic behavior in a rotating drum by CFD method and obtained the different solid flows and velocity distributions of the particulate phase.[27] Shi et al. performed a CFD method to analyze the liquid-phase flow within rotating packed bed (RPB) reactors and obtained the velocity and distribution of the liquid in RPB and the interface between gas–liquid phases.[28] Tang et al. used the CFD method to investigate a mixing process in a solid–liquid rotary drum and determine the effect of rotation speed on particle behaviors and flow characteristics.[29]

Therefore, in the present work, an attempt was made to quantitatively clarify the influence of typical leather motions on chemicals' mass transfer in leather by experimental and CFD simulation methods. Different leather motions were prepared by adjusting the drum rotation speed, as described in a previous work.[30] Pickled cattle hides were tanned with an environmentally friendly zirconium tanning agent under the different leather motions. Then, the adsorption kinetics of the tanning agent and the tanning performance of leather were analyzed to determine the relationship between leather motions and chemicals' transfer and reaction. Moreover, the velocity distributions of flow field and the mass transfer rates of the zirconium tanning agent under each typical motion state were investigated by CFD simulation based on the experimental data [Figure 1(c)] to further explain how leather motion states affect the mass transfer rate of chemicals. Here, it is worth noting that although the chrome tanning method is the most common tannage used in the leather industry, it generates chromium-containing wastewaters and solid wastes.[31,32] Therefore, chrome-free tannages have received much attention in recent years.[33] Zirconium tanning is a typical chrome-free tannage, and zirconium is easily detected by energy-dispersive X-ray spectroscopy (EDS) and inductively coupled plasma optical emission spectrometry (ICP-OES).[34] Moreover, the transfer rate and distribution uniformity of the zirconium tanning agent in the hide are inferior to those of the chrome tanning agent,[35] and thus the difference in the tanning performance under various rotation speeds can be observed more easily during zirconium tanning. For these reasons, zirconium tanning was chosen to investigate the tanning process in this work. This study is expected to identify the leather motion state that is more beneficial for chemicals' mass transfer and provide basic guidance on the optimization of operating conditions and the design of novel drum.

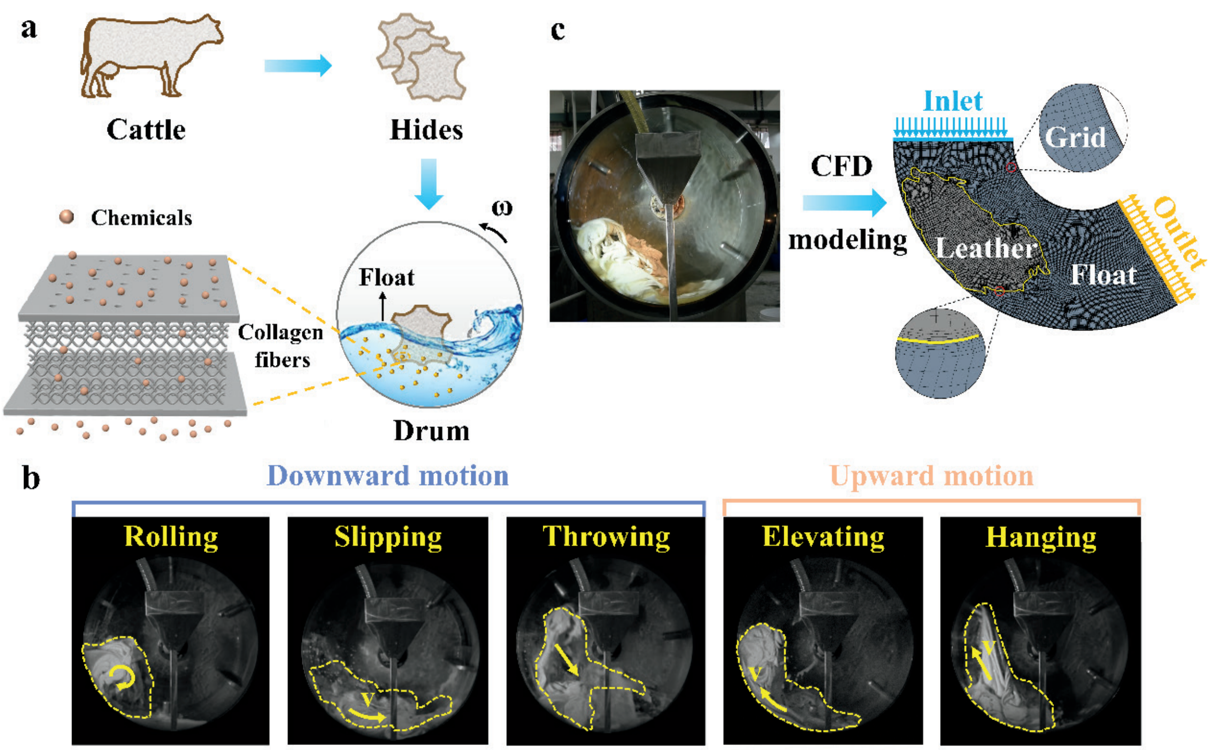


Figure 1. **(a)** Schematic of leather manufacturing. **(b)** Five typical motion states of leather in a rotating drum. **(c)** CFD modeling.

Experimental

Materials

Pickled cattle hides (pH 3.0, 1.5 mm thickness) and zirconium tanning agent of technical grade were provided by Sichuan Tingjiang New Material Co., Ltd. (Shifang, China). Analytical-grade magnesium oxide, nitric acid (65%–68% w/v aqueous solution) and hydrogen peroxide (30% w/v aqueous solution) were purchased from Chron Chemicals Co., Ltd. (Chengdu, China). The other chemicals used for leather processing were of technical grade.

Tanning experiments

Four pickled cattle hides were tanned with zirconium tanning agent to obtain leathers, as shown in Table I. Each pickled hide of approximately 10 kg was divided into four pieces (cut along directions parallel and perpendicular to the backbone) and used for a tanning trial. The drum rotation speed was individually set to 5, 10, 15, and 20 r/min. The motion characteristics of leather during tanning were analyzed by a visualization experiment system. The mass transfer behaviors of zirconium in leather were studied by measuring the change in the zirconium concentration of the tanning float and the zirconium content of leather. Tanning performance was evaluated by measuring the shrinkage temperatures and fiber dispersion of zirconium-tanned leathers.

Visualization of leather motions

The motion characteristics of leather were investigated by a visualization experiment system as shown in Figure 2. The drum rotation speed is in the range of 0–25 r/min, and the internal diameter and width of the drum were 800 and 400 mm, respectively. The front-end plate of the drum is transparent for easy observation of leather motions. Two baffles (90 mm width) and six cylindrical columns (30 mm diameter) are symmetrically arranged inside the drum. Three light sources were placed to reduce the negative impacts caused by uneven light distribution. A camera with 25 frames per second (fps) and a resolution of 1920×1080 pixels was placed 1200 mm away from the drum to capture the real-time position of the leather [Figure 2(c)]. The horizontal and vertical directions of the camera were calibrated by a laser leveler, where the lens was perpendicular to the image before shooting. A laptop was used to process the videos immediately to facilitate further data analysis. Adobe Premiere was used to edit the video [Figures 2(d) and 2(e)]. Image analysis was conducted using MATLAB to convert the original image into a binary image [Figure 2(f)], assigning 0 for drum areas (black) and 1 for the leather (white). The occurrence frequency and time percentage of each motion state of leather were counted.

As for the calculation of leather velocity, the shape center of leather was regarded as the centroid of leather, assuming a uniform density of leather. The instantaneous centroid coordinates of leather were extracted according to the binary image of each frame, the centroid displacement between two frames was measured, and the change of leather velocity within one frame (1/25 s) was ignored. The average velocity of leather in this frame was calculated and considered the instantaneous velocity of leather motion in this study.

Table I
Zirconium tanning process

Process	Material	Dosage (%)*	T (°C)	t (min)	Remarks
Pickling	Water	200	20		
	Sodium chloride	14		10	
	Pickled hide			20	Drain 40% float.
Tanning	Zirconium tanning agent	14	20	240	
Basifying	Magnesium oxide	2.2		180	
	Water	200	40	120	Still overnight. Next day, run 30 min.

*The percentages of materials were based on the weight of pickled cattle hide.

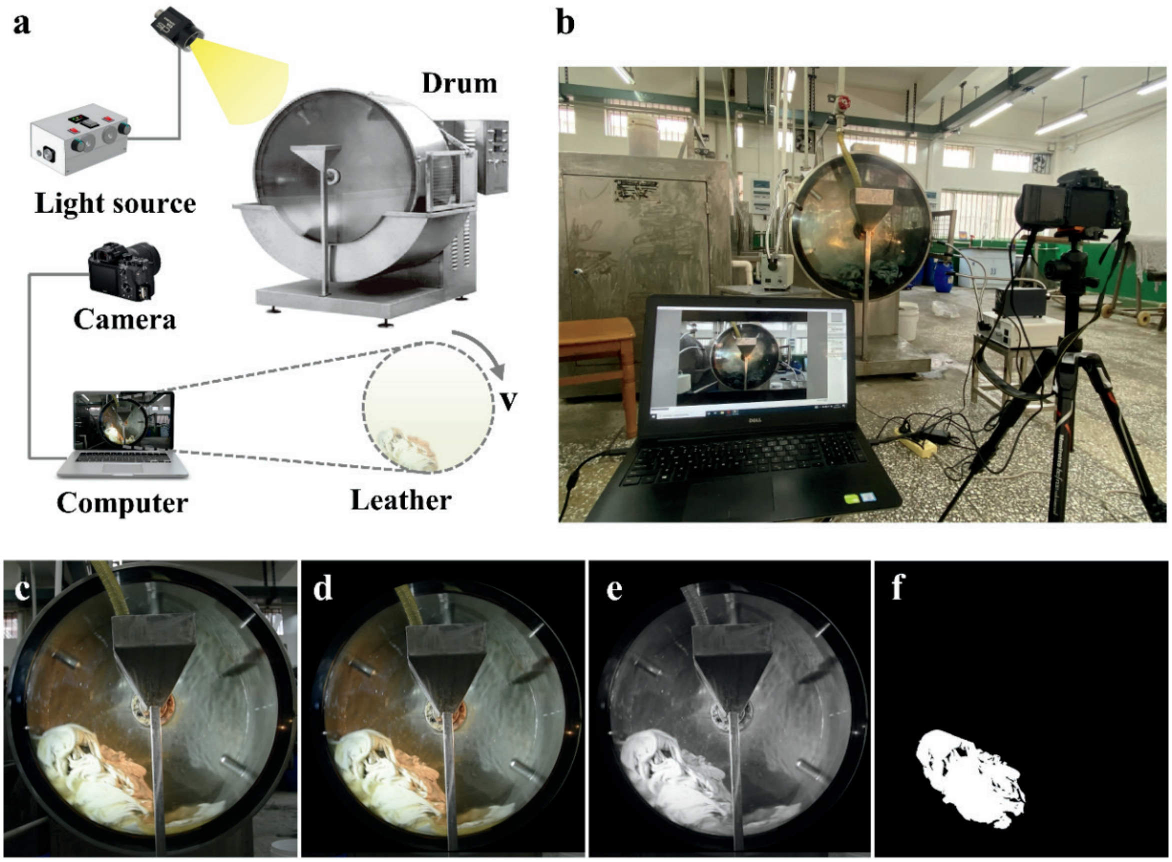


Figure 2. Visualization experiment: **(a)** Schematic of experiment system. **(b)** Photograph of the experimental system. **(c-f)** Processing of leather motion images: **(c)** shooting; **(d)** cutting; **(e)** gray processing; **(f)** binarizing.

Analysis of mass transfer of zirconium tanning agent in leather

Float samples were collected after tanning for 5, 10, 20, 30, 40, 60, 90, 120, 180 and 240 min. One mL of float sample was digested with 5 mL of nitric acid aqueous solution (65% *w*/*v*) and 1 mL of hydrogen peroxide aqueous solution (30% *w*/*v*) at 4 MPa and 200°C for 55 min in a microwave digestion instrument (Multiwave PRO, Anton Paar, Austria). The zirconium concentration of the digestion solution was determined by ICP-OES (Optima 2100DV, PerkinElmer, USA). The uptake of zirconium tanning agent by the leather was calculated with Equation (1):

$$\text{Zirconium uptake} = (C_0\text{-}C_t) / C_0 \times 100\% \tag{1}$$

where C_0 (mg/L) is the initial zirconium concentration of the tanning float, and C_t (mg/L) is the zirconium concentration of the float after tanning for t min.

Moreover, the leathers were sampled after tanning for 5, 30, 60, 90, 120, 180 and 240 min. The zirconium distribution in the leather was detected by EDS (INCA X-MAX 50, Oxford, UK). The leather samples were further split into three uniform layers, and each layer was dried to a constant weight at 102°C. Dried sample (0.5 g) was digested with 5 mL of nitric acid and 1 mL of hydrogen peroxide. The zirconium concentration of the digestion solution was measured by ICP-OES. The zirconium content of each layer was calculated using Equation (2):

$$\text{Zirconium content} = (c \times V) / w \times 100\% \tag{2}$$

where c is the zirconium concentration of the digestion solution (mg/L), V is the volume of the digestion solution (L), and w is the dry weight of the leather sample (mg).

Here, the total weight of the leather samples used for measuring the zirconium concentration was less than 50 g, viz. 0.5% of the total hide weight. Therefore, the hide weight loss affected the calculation of zirconium concentration slightly and was negligible.

The measurements were repeated thrice to obtain the average values and standard deviations.

Analysis of leather tanning performance

The leathers were horsed up for 24 h after tanning and sampled to determine the shrinkage temperature and porosity of zirconium-tanned leather. The shrinkage temperature was measured according to the standard method.[36] The porosity and morphology of the leather were analyzed by mercury intrusion porosimetry (MIP; AutoPore IV 9500, Micromeritics, USA) and scanning electron microscopy (SEM;

JSM-7500F, JEOL, Japan), respectively, using the leather samples lyophilized in a freeze dryer (LGJ-30F, XinYi, China).

CFD validation of leather motion states

Assumptions and governing equations

The following assumptions were performed to make the simulation results close to the actual situations and save computing time:

(i) The tanning float was assumed as an incompressible Newtonian fluid and the mixture of zirconium and water.

(ii) The tanning float was assumed as a turbulent and two-dimensional (2D) fluid and filled the whole computing region.

(iii) The physical properties of the fluid were the same with those of water.

(iv) The leather was considered as a 2D porous model with fluid inside.

The error resulting from the assumption for 2D modeling was caused by ignoring the leather deformation in the vertical direction of drum, and the error margin was ±27.4%.

Considering these assumptions, the governing equations for fluid flow are as follows.[37]

Continuity equation:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{3}$$

where u and v are velocity components in x, y directions, m/s; x and y are coordinate directions, m.

Momentum equations:

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+v\frac{\partial^2 u}{\partial y^2}\right) \tag{4}$$

$$\rho\left(u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+v\frac{\partial^2 v}{\partial y^2}\right) \tag{5}$$

where ρ is the density of fluid, kg/m^3; p is the operating pressure in the drum, Pa; μ is the dynamic viscosity of the fluid, kg/s.

Energy equation:

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=a\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right) \tag{6}$$

where T is the temperature of fluid, K; a is the thermal diffusion coefficient, m^2/s

Concentration equation:

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_{AB}\left(\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial y^2}\right) \tag{7}$$

where C is the zirconium concentration in the fluid, kg/m^3; D_{AB} is the diffusion coefficient of zirconium in the fluid, m^2/s.

Boundary conditions

The boundary conditions are as follows:[38]

Fluid inlet: $u = u(t)$, $c = c_0$

Fluid outlet: $u = u(t)$

Leather surface: $u = 0$, $c = 0$

where $u(t)$ is the velocity of the fluid and set as a value based on the calculated results of the visualisation experiment, m/s. c_0 is the initial zirconium concentration in the fluid and calculated with equation (8), 3.4 mg/g.

$$c_0=\frac{P_1\times P_2\times M(\mathrm{Zr})}{P_3\times M(\mathrm{ZrO_2})} \tag{8}$$

where P_1 and P_3 are the mass percentages of the zirconium tanning agent and the float used in the tanning experiment, respectively; P_2 is the mass percentage of zirconium dioxide in the zirconium tanning agent; M(Zr) and M(ZrO_2) are the relative molecular masses of zirconium and zirconium dioxide, respectively.

Figure 3 shows the 2D geometric modelling for the tanning process. Based on the binarization image, the geometric feature of the leather

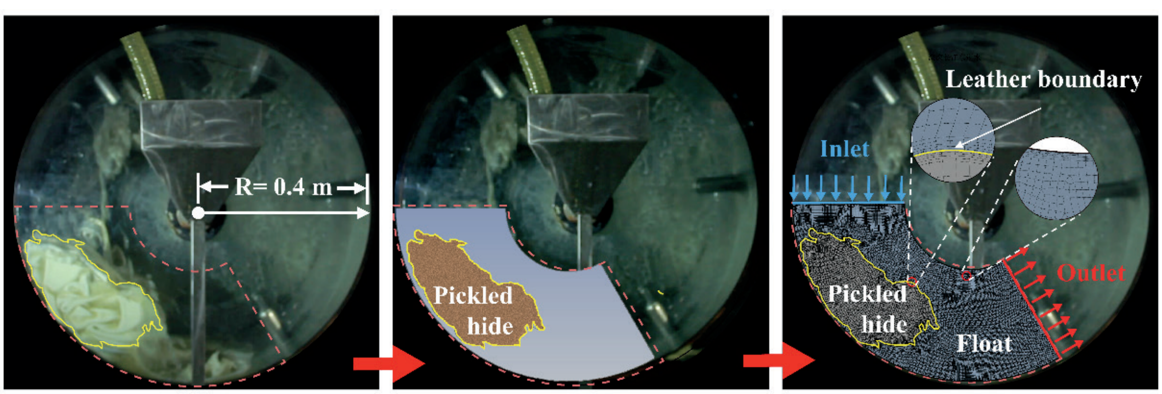


Figure 3. CFD modeling for tanning process (15 r/min).

was presented in the model. Auto CAD software was used to draw the outline of leather, and then the Ansys ICEM software was used to generate a quadrilateral mesh.

The velocity values of rolling, slipping, throwing, elevating and hanging motions were 0.23, 0.31, 0.35, 0.36 and 0.25 m/s, respectively. The mass transfer diffusion coefficient of zirconium was set as 2.88×10^{-5} m^2/s based on the evaluation method performed by Sathish.[39] Leather was defined as a porous medium whose porosity was set as 0.50 according to the MIP measurement results. The viscosity resistance coefficient and inertia resistance coefficient of leather were defined as the default values corresponding to 2.11×10^{8} and 4.39, respectively.

Results and Discussion

Leather motion characteristics under different rotation speeds

During the tanning process, leathers shrink into ball shapes in the drum [Figure 2(c)] and represent motions with consecutive deformation [Figure 1(b)]. These irregular motions will lead to the ever-changing mass transfer behaviors of tanning agents. The aim of this work was to reveal the quantitative relationship between typical leather motions and the mass transfer of chemicals. Therefore, different leather motions were prepared by adjusting the drum rotating speed from 5 r/min to 20 r/min.

We previously found that five typical motion states of leather occur in the tanning process, where the rolling, slipping and throwing states were classified into downward motions, and the elevating and hanging states were classified into upward motions [Figure 1(b)].[30] In this study, the tanning images in one minute were captured using the visualization experiment system after the drum rotated stably, and the occurrence frequency and time percentage of each motion state of leather were counted. As shown in Figure 4(a), the duration of each motion state differs with increasing drum rotation speed. The rolling, slipping and elevating states of leather were the motion states that occurred most frequently in the tanning process, whose total duration was more than 80% of the tanning time. As the rotating speed increased from 5 r/min to 20 r/min, the durations of the rolling, slipping, throwing, and hanging states increased by 9.8%, 20.8%, 23.9%, and 59.7%, respectively; the duration of the elevating state decreased by 67.5%. No obvious differences in the height of elevating and throwing were observed under different rotation speeds of the drum. Figure 4(b) presents that the durations of upward and downward motions showed a logarithmic relationship with the drum rotation speed. In summary, leathers with different motion characteristics were obtained using different drum rotation speeds.

Mass transfer of zirconium tanning agent

Mass transfer of tanning agents is of great importance for tanning performance and leather properties.[40] In this section, the mass transfer of the zirconium tanning agent was evaluated by analyzing the adsorption kinetics of zirconium to leather and the distribution of zirconium in leather. The adsorption amounts of the zirconium tanning agent by leather increased over time and with increasing rotation speed [Figures 5(a)] and 5(b)]. The time for the adsorption equilibrium of zirconium under 15 and 20 r/min was approximately 120 min, whereas that under 5 and 10 r/min was approximately 180 min. The results suggested that the penetration process can be shorten by increasing drum rotation speed. The adsorption kinetics data were further fitted to pseudo-first-order (PFO) and pseudo-second-order (PSO) kinetic models. The PFO and PSO kinetic equations are as follows:[41,42]

$$\ln(q_e - q_t) = \ln q_e - k_1 t \quad (9)$$

$$\frac{t}{q_t} = \frac{1}{q_e} t + \frac{1}{k_2 q_e^2} \quad (10)$$

where q_t and q_e are the amounts of zirconium adsorbed (mg/g) at t min and equilibrium, respectively, and k_1 and k_2 are the PFO rate constants (min^{-1}) and the PSO rate constants (g/[mg·min]), respectively.

The PFO and PSO kinetic parameters for zirconium adsorption during the tanning process are listed in Table II. The correlation

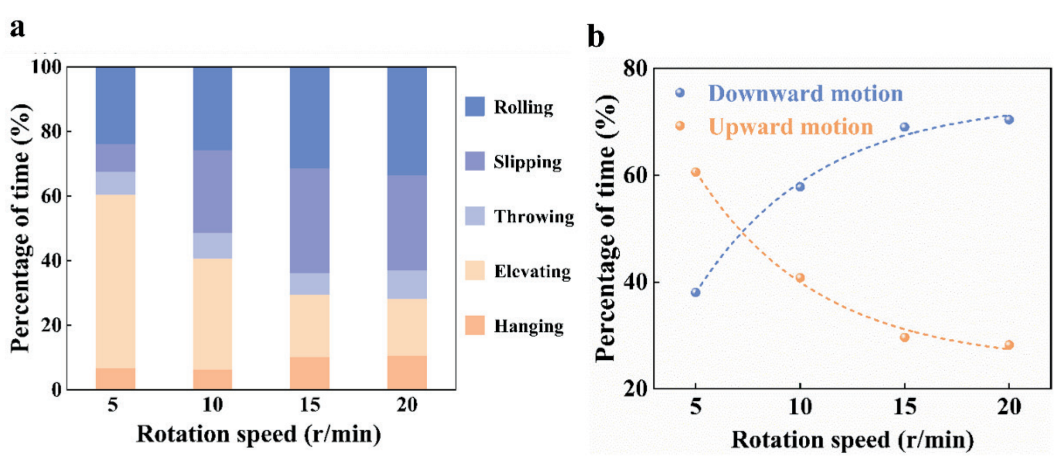


Figure 4. Motion characteristics of leather in the tanning process under different drum rotation speeds: **(a)** Percentage of duration of each motion state of leather during tanning process. **(b)** Fitting curves showing the relationship between the durations of upward and downward motions of leather and the drum rotation speed during tanning process.

Table II
PSO and PFO kinetic parameters for zirconium adsorption

Group	$q_e\,exp$ (mg/g)	PFO kinetic model				PSO kinetic model			
		k_1 (min^{-1})	R^2	$q_e\,cal$ (mg/g)	Error (%)	k_2 (g/(mg·min)$^{-1}$)	R^2	$q_e\,cal$ (mg/g)	Error (%)
5 r/min	30.76	5.03×10^{-2}	0.6925	28.83	6.27	3.15×10^{-4}	0.9963	31.50	-2.41
10 r/min	42.36	3.64×10^{-2}	0.7738	40.07	5.41	2.59×10^{-3}	0.9962	43.18	-1.94
15 r/min	48.71	5.62×10^{-2}	0.7984	47.29	2.92	2.90×10^{-3}	0.9994	49.95	-2.55
20 r/min	48.15	5.80×10^{-2}	0.6252	45.79	1.79	2.75×10^{-3}	0.9983	49.65	-3.11

$q_e\,exp$: determined by experiments.

$q_e\,cal$: calculated by the PFO or PSO kinetic models.

Error (%) = $(q_e\,exp - q_e\,cal)/q_e\,exp \times 100$.

R^2: correlation coefficient.

coefficients (R^2) obtained by the PSO kinetic model were all higher than 0.99, whereas those obtained by the PFO kinetic model were lower than 0.80. The results indicated that the zirconium adsorption processes followed the PSO kinetics [Figure 5(c)]. Moreover, the higher k_2 values for tanning under 15 and 20 r/min than those under 5 and 10 r/min indicated that high rotation speed resulted in the rapid adsorption of zirconium. The data in Figure 5(d) shows the amounts of zirconium absorbed by each layer of leather under different rotation speeds. The amounts of zirconium absorbed by the middle layer were lower than those absorbed by the grain and flesh layers under 5 and 10 r/min, and the amounts of zirconium absorbed by the middle layer were close to those absorbed by grain and flesh layers under 15 and 20 r/min. The results indicated that the zirconium was distributed more evenly in the tanned leather under higher rotation speed. In summary, tanning under high rotation speed achieved better mass transfer than tanning under low rotation speed. In addition, no apparent differences in the adsorption amounts and rates of zirconium were observed between 15 and 20 r/min, which suggested that the transfer and uptake of zirconium could not be further improved by increasing the rotation speed above 15 r/min.

The tanning performance of leather was evaluated by analyzing the shrinkage temperature (for characterizing hydrothermal stability) and fiber dispersion of leather. The high shrinkage temperature and fiber dispersion degree of leather represent excellent tanning performance. As shown in Figure 5(e), the shrinkage temperature of leather gradually increases as the rotating speed increased from 5/min to 15 r/min. SEM images of the leather cross-sections showed that the leather collagen fibers tanned under high rotation speed were highly dispersed [Figure 5(f)]. Overall, leather tanned under high rotation speed exhibited excellent tanning performance, because high rotation speed resulted in rapid zirconium penetration, uniform zirconium distribution and high zirconium uptake. The tanning performance under 15 and 20 r/min were similar, which may be explained by the fact that the penetration, distribution and uptake of zirconium under 15 r/min were close to those under 20 r/min.

Effect of leather motion states on mass transfer analyzed by CFD

Leather is a fibrous material that has multiple hierarchical structures and unevenly distributed pores [Figure 5(f)]. Pores in the leather matrix always deform during the tanning process, which makes a connection between the leather and float in the drum. The connection presents diverse and transient features, resulting in the varying mass transfer of zirconium at different moments. The data in Figures 4 and 5 demonstrate that different rotation speeds lead to different leather motions and mass transfer rates of zirconium. As the rotation speed increased, the durations of the rolling and slipping states increased, and the mass transfer of zirconium and leather tanning performance were improved. The results implied that leather motion has a strong connection with the mass transfer of tanning agent, and the rolling and slipping states should be conducive to the mass transfer. In this section, the CFD method was therefore used to further analyze the flow field of the float and the mass transfer of zirconium under typical leather motion states to clarify the effects of leather motion states on the mass transfer.

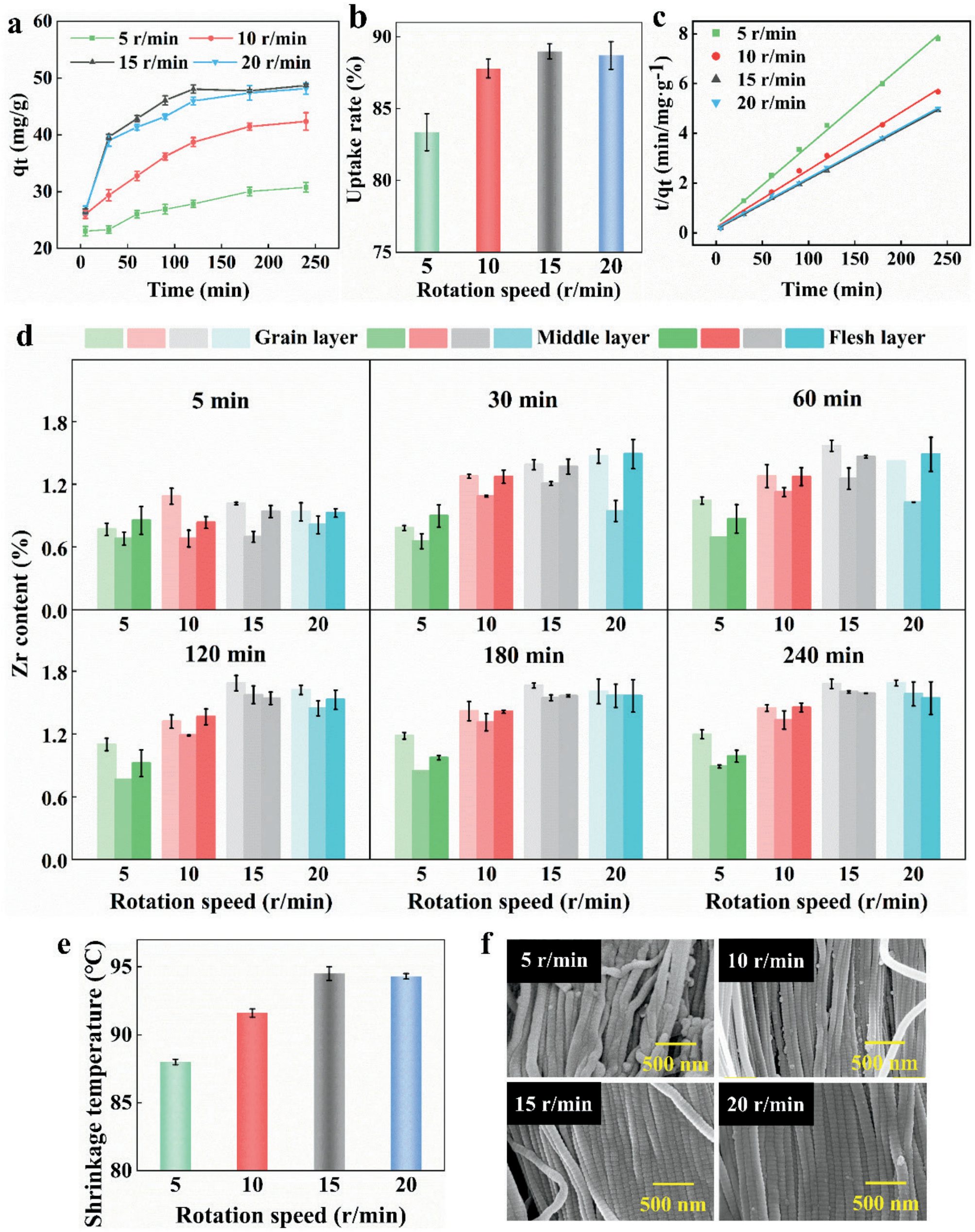


Figure 5. Adsorption kinetics and tanning performance of tanning agent under different rotation speeds. **(a)** Adsorption amount of zirconium by leather over time. **(b)** Uptake rate of zirconium tanning agent. **(c)** Fitting of zirconium adsorption data to the PSO kinetic model. **(d)** Zirconium distribution in grain, middle and flesh layers of leather. **(e)** Shrinkage temperature of leather. **(f)** SEM images of the cross-sections of leathers.

Velocity distribution

Figure 6 shows the instantaneous flow field of the float under five typical leather motion states. The maximum velocity of the float was 1.92 m/s during leather throwing, which was 2.56 times of that during leather hanging. This result indicates that the motion states of leather have a great influence on the flow field. The maximum velocity of the float was higher than 1.5 m/s when the leather was under slipping, throwing and rolling motions (downward motions), whereas the maximum velocity of the float was less than 1 m/s when the leather is elevating and hanging (upward motions). This outcome may be due to the downward motions of leather propelling the flow of the float. The float velocity near the rolling leather surface was the highest, which may be attributed to the strong scouring action of the float on the rolling leather surface. The rolling motion contributed the most to rapid float flow, which implies that the rolling motion should be most beneficial to the mass transfer of tanning agent.

Mass transfer of zirconium

Mass transfer analysis was conducted based on the data in steady-state, where the amounts of zirconium in the leather and float were at equilibrium and the mass transfer was suspended. The mass

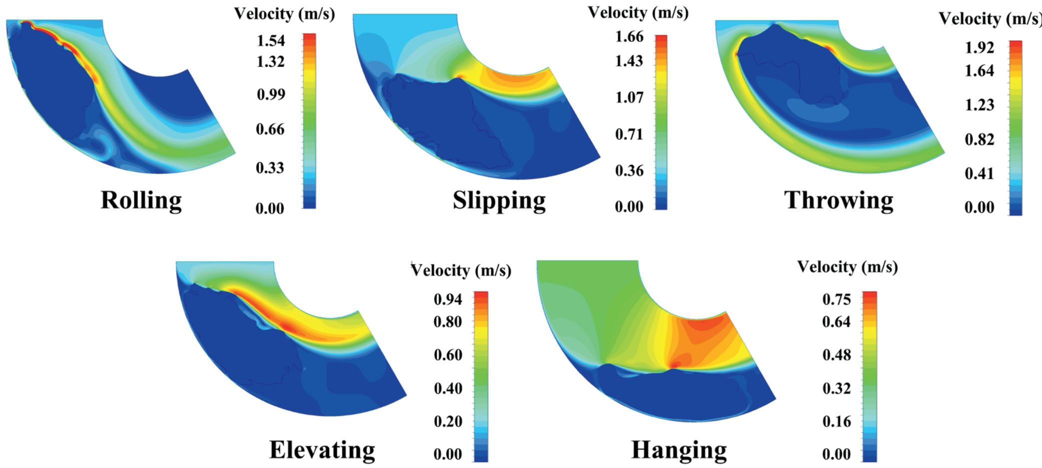


Figure 6. Flow field under five typical leather motion states.

fractions of zirconium in the float when the leather was under five typical motion states are shown in Figure 7. The zirconium concentration gradients near the leather surface were higher during leather throwing and rolling, compared with during leather slipping and hanging. The results means that the rolling and throwing of leather are more conducive to the mass transfer of zirconium than the other three motion states.

The simulated mass transfer rates of zirconium under the different leather motion states were calculated by Fick's law:

$$M_r = \frac{D_{AB}}{L_W}\int_0^{L_w} \frac{\partial C}{\partial Y}\bigg|_{Y=0} dl \tag{11}$$

where M_r is the simulated mass transfer rate of zirconium, mg/(m^2·s); D_{AB} is the diffusion coefficient of zirconium in the float, m^2/s; L_W is the length of the leather boundary, m; C is the zirconium concentration in the float, kg/m^3; dl is the microelement of leather boundary, m; Y is the penetration depth of zirconium in leather, m.

Considering that the zirconium mass transfer rate at a specific moment in the experiment is difficult to obtain, the given data are the averaged values calculated using Eq. (12):

$$\overline{M_r} = \frac{M_{Zr} \bullet \rho_H \bullet L_H}{m_H t_M} \tag{12}$$

where $\overline{M_r}$ is the average value of the mass transfer rate of zirconium in the experiment, mg/(m^2·s); M_{Zr} is the mass of zirconium absorbed by the leather at the end of the tanning process, mg; ρ_H is the density of the pickled hide, 1.432 kg/m^3; L_H is the thickness of the pickled hide, m; m_H is the mass of the pickled hide, kg; t_M is the time for the adsorption equilibrium of zirconium, s.

The simulated zirconium mass transfer rates were compared with the experimental data (Figure 8). The mass transfer rates of zirconium during leather throwing and rolling were obviously higher than those during the other three motions. This result indicates that leather's throwing and rolling motions play important roles in the mass transfer. Increasing the duration of the throwing and rolling

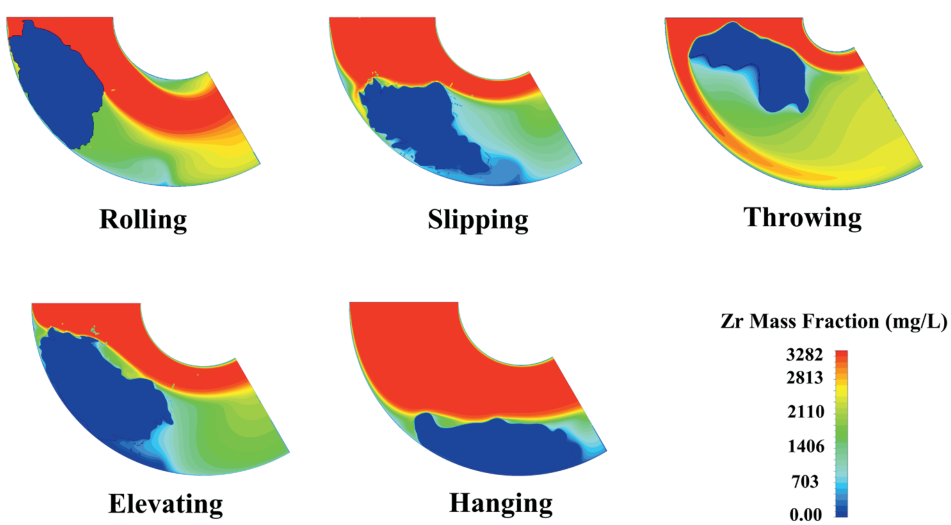


Figure 7. Mass fractions of zirconium under five typical leather motion states.

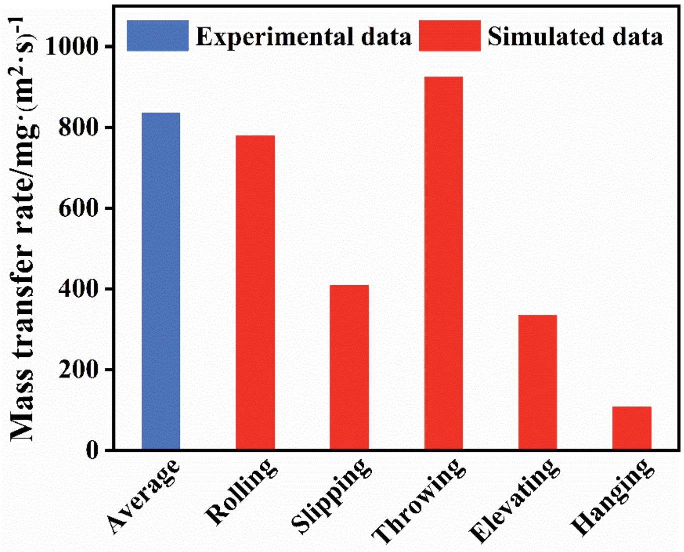


Figure 8. Comparison between experimental and simulated results (15 r/min).

states in leather production is beneficial to enhancing mass transfer and shortening tanning time. The average values of zirconium mass transfer rates in the experiment were nearly 1.5 times of the simulated values (15 r/min), which may be caused by the rapid suction and ejection of the float within leather pores. Future work will further elucidate how the porous structure of leather affects the mass transfer of chemicals. Notably, the loading rate of drum greatly affects the motions of leather and the mass transfer of chemicals. The applicability of this model at a high loading rate of drum needs to be further verified.

Conclusion

Leather motion states were closely related to the mass transfer and distribution of tanning agent in leather and the tanning performance of leather. Rolling motion was beneficial for the rapid penetration and uniform distribution of tanning agent, whereas hanging motion had the opposite effect. Rapid penetration leads to high-efficiency production and uniform distribution of tanning agent leads to excellent tanning performance. The results indicate that greater tanning performance can be achieved by increasing rolling motion and decreasing hanging motion. This work proposes a clear direction to regulate mechanical actions, which is useful for designing operating conditions or novel equipment for high-quality leather production.

Acknowledgement

This work was supported by Natural Science Foundation of Sichuan Province (2022NSFSC1180) and Research Institutes of Leather and Footwear Industry of Wenzhou (20H1061).

References

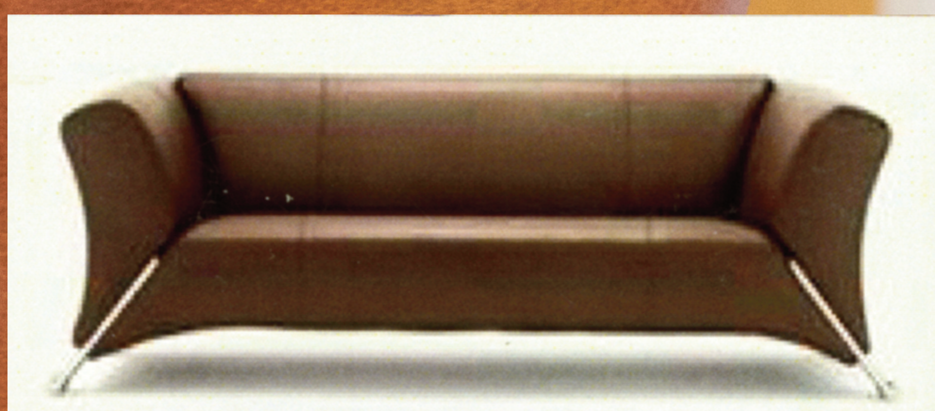
1. Dixit, S., Yadav, A., Dwivedi, P.D., Das, M.; Toxic hazards of leather industry and technologies to combat threat: a review. *J. Clean. Prod.* **87**, 39-49, 2015.
2. Saravanabhavan, S., Thanikaivelan, P., Rao, J.R., Nair, B.U., Ramasami, T.; Reversing the conventional leather processing sequence for cleaner leather production. *Environ. Sci. Technol.* **40(3)**, 1069-1075, 2006.
3. Covington, A. D.; Tanning Chemistry: The Science of Leather, Royal Society of Chemistry, Cambridge, 195-201, 2009.
4. Hansen, É., de Aquim, P.M., Hansen, A.W., Cardoso, J.K., Ziulkoski, A.L., Gutterres, M.; Impact of post-tanning chemicals on the pollution load of tannery wastewater. *J. Environ. Manag.* **269**, 110787, 2020.
5. Garcia, N.G., dos Reis, E.A.P., Budemberg, E.R., Agostini, D.L.D.S., Salmazo, L.O., Cabrera, F.C., Job, A.E.; Natural rubber/leather waste composite foam: A new eco-friendly material and recycling approach. *J. Appl. Polym. Sci.* **132(11)**, 2015.
6. He, X., Ding, W., Yu, Y., Zhou, J. F., Shi, B.; Insight into the correlations between fiber dispersion and physical properties of chrome tanned leather. *JALCA* **115(1)**, 23-29, 2020.
7. Sun, S., Wang, X., Zhu, X., Liu, X., Guo, P., Tian, Y.; Synthesis of an amphiphilic amphoteric peptide-based polymer for organic chrome-free ecological tanning. *J. Clean. Prod.* **330**, 129880, 2022.
8. Mao, Q., Yang, Q. J., Liu, Y., Cao, W.; Experimental and numerical study of droplet formation with Marangoni instability. *Chem. Eng. Sci.* **268**, 118369, 2023. Zheng et al., 2014
9. Yao, Y.; Enhancement of mass transfer by ultrasound: Application to adsorbent regeneration and food drying/dehydration. *Ultrason. Sonochem.* **31**, 512-531, 2016.
10. Wegener, M., Paschedag, A.R. and Kraume, M.; Mass transfer enhancement through Marangoni instabilities during single drop formation. *Int. J. Heat. Mass. Tran.* **52(11-12)**, 2673-2677, 2009.
11. Ahmed, S.M., Phan, A.N., Harvey, A.P.; Mass transfer enhancement as a function of oscillatory baffled reactor design. *Chem. Eng. Process.* **130**, 229-239, 2018.
12. Dehghannya, J., Pourahmad, M., Ghanbarzadeh, B., Ghaffari, H.; Heat and mass transfer enhancement during foam-mat drying process of lime juice: Impact of convective hot air temperature. *Int. J. Therm. Sci.* **135**, 30-43, 2019.
13. Fishwick, R. P., Winterbottom, J. M., Stitt, E. H.; Effect of gassing rate on solid–liquid mass transfer coefficients and particle slip velocities in stirred tank reactors. *Chem. Eng. Sci.* **58(3-6)**, 1087-1093, 2003.
14. Mohammed, I., Bauer, T., Schubert, M., Lange, R.; Liquid–solid mass transfer in a tubular reactor with solid foam packings. *Chem. Eng. Sci.* **108**, 223-232, 2014.
15. Wang, Y.N., Hu, L.; Essential role of isoelectric point of skin/leather in leather processing. *J. Leather Sci. Eng.* **4(1)**, 25, 2022.
16. Yang, T. Q., Zeng, Y. H., Sun, Q. Y., Lei, C., Shi, B.; Effect of pickling materials on leather quality from a hide surface charge perspective. *JALCA* **117(7)**, 279-87, 2022.

17. Wang, Y.N., Huang, W. L., Zhang, H., Tian, L., Zhou, J. F., Shi, B.; Surface charge and isoelectric point of leather: a novel determination method and its application in leather making. *JALCA* **112(07)**, 224-231, 2017.
18. Yu, Y., Wang, Y.N., Ding, W., Zhou, J. F., Shi, B.; Preparation of highly-oxidized starch using hydrogen peroxide and its application as a novel ligand for zirconium tanning of leather. *Carbohyd. Polym.* **174**, 823-829, 2017.
19. Ma, J., Gao, J., Wang, H., Lyu, B., Gao, D.; Dissymmetry gemini sulfosuccinate surfactant from vegetable oil: A kind of environmentally friendly fatliquoring agent in the leather industry. *ACS Sustain. Chem. Eng.* **5(11)**, 10693-10701, 2017.
20. Ma, J.Z., Liu, Q., Wu, M., Tian, Z.; Preparation and assistant-dyeing of formaldehyde-free amphoteric acrylic retanning agent. *J. Leather Sci. Eng.* **3**, 1-13, 2021.
21. Wang, X., Lan, X., Zhu, X., Sun, S.; Preparation of a ricinolein acid modified amphoteric polyurethane for leather cleaner and simplifying production. *J. Clean. Prod.* **330**, 129877, 2022.
22. Ariram, N., Sathish, M., Madhan, B.; Chemical/water-free deliming process using supercritical carbon dioxide: a step toward greener leather manufacture. *ACS Sustain. Chem. Eng.* **8(31)**, 11747-11754, 2020.
23. Sathish, M., Silambarasan, S., Madhan, B., Rao, J.R.; Exploration of GSK'S solvent selection guide in leather industry: a CSIR-CLRI tool for sustainable leather manufacturing. *Green. Chem.* **18(21)**, 5806-5813, 2016.
24. Kanagaraj, J., Panda, R.C., Senthilvelan, T., Gupta, S.; Cleaner approach in leather dyeing using graft copolymer as high performance auxiliary: related kinetics and mechanism. *J. Clean. Prod.* **112**, 4863-4878, 2016.
25. Wang, Z., Wang, Y.N., Yu, Y., Shi, B.; Tanning performance of a novel chrome-free complex tanning agent: penetration and distribution. *JALCA* **116(8)**, 277-283, 2021.
26. Ding, W.; Bridging-induced densification strategy based on biomass-derived aldehyde tanning integrated with terminal Al (III) crosslinking towards high-performance chrome-free leather production. *J. Environ. Manage.* **307**, 114554, 2022.
27. Santos, D.A., Petri, I.J., Duarte, C.R., Barrozo, M.A.S.; Experimental and CFD study of the hydrodynamic behavior in a rotating drum. *Powder. Technol.* **250**, 52-62, 2013.
28. Shi, X., Xiang, Y., Wen, L.X., Chen, J.F.; CFD analysis of liquid phase flow in a rotating packed bed reactor. *Chem. Eng. J.* **228**, 1040-1049, 2013.
29. Tang, X., Yue, Y., Wang, S., Shen, Y.; Modelling of gas-solid-liquid flow and particle mixing in a rotary drum. *Powder. Technol.* **409**, 117758, 2022.
30. Jiang, Z.C., Lin, Y.R., Xie, G., Zeng, Y.H., Wang, Y.N.; Motion characteristics of leather in drum and influence on mass transfer for chemicals. *Chemical Engineering (China).* **50(8)**, 26-30, 2022.
31. Tang, Y. L., Zhao, J. T., Zhou, J. F., Zeng, Y. H., Zhang, W. H. and Shi, B.; Highly efficient removal of Cr (III)-poly (acrylic acid) complex by coprecipitation with polyvalent metal ions: Performance, mechanism, and validation. *Water Res.* **178**, 115807, 2020.
32. Li, Y. C., Guo, R. J., Lu, W. H. and Zhu, D. Y.; Research progress on resource utilization of leather solid waste. *Journal of Leather Science and Engineering* **1**, 1-17, 2019.
33. Yu, Y., Lin, Y. R., Zeng, Y. H., Wang, Y. N., Zhang, W. H., Zhou, J. F. and Shi, B.; Life cycle assessment for chrome tanning, chrome-free metal tanning, and metal-free tanning systems. *ACS Sustainable Chem. Eng.* **9(19)**, 6720-6731, 2021.
34. Yu, Y., Wang, H., Wang, Y., Zhou, J. F. and Shi, B.; Construction of a chrome-free tanning system based on highly-oxidized starch–zirconium complexes. *JALCA* **117(3)**, 87-95, 2022.
35. Yu, Y., Wang, H., Wang, Y.N., Zhou, J. F. and Shi, B.; Chrome-free synergistic tanning system based on biomass-derived hydroxycarboxylic acid–zirconium complexes. *J. Clean. Prod.* **336**, 130428, 2022.
36. IUP 16; Measurement of shrinkage temperature up to 100°C. *J. Soc. Leath. Tech. Ch.* **84**, 359–362, 2000.
37. Wang, X., Wang, Y., Chen, H., Zhu, Y.; A combined CFD/visualization investigation of heat transfer behaviors during geyser boiling in two-phase closed thermosyphon. *Int. J. Heat. Mass. Tran.* **121**, 703-714, 2018.
38. Talukdar, P., Iskra, C.R., Simonson, C.J.; Combined heat and mass transfer for laminar flow of moist air in a 3D rectangular duct: CFD simulation and validation with experimental data. *Int. J. Heat. Mass. Tran.* **51(11-12)**, 3091-3102, 2008.
39. Sathish, M., Dhathathreyan, A., Rao, J.R.; Ultraefficient tanning process: role of mass transfer efficiency and sorption kinetics of Cr (III) in leather processing. *ACS Sustain. Chem. Eng.* **7(4)**, 3875-3882, 2019.
40. Gao, D., Wang, P., Shi, J., Li, F., Li, W., Lyu, B., Ma, J.; A green chemistry approach to leather tanning process: cage-like octa (amino-silsesquioxane) combined with Tetrakis (hydroxymethyl) phosphonium sulfate. *J. Clean. Prod.* **229**, 1102-1111, 2019.
41. Ho, Y.S., McKay, G.; Pseudo-second order model for sorption processes. *Process. Biochem.* **34(5)**, 451-465, 1999.
42. Haerifar, M., Azizian, S.; An exponential kinetic model for adsorption at solid/solution interface. *Chem. Eng. J.* **215**, 65-71, 2013.

LEATHER

AVELLISYNCO

Selected Dyestuffs



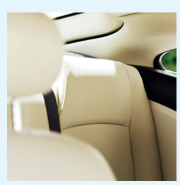
CHEMTAN

17 Noble Farm Drive • Lee, NH 03861 (Office)
57 Hampton Road • Exeter, NH 03833 (Manufacturing)
Tel: (603) 772-3741 • Fax: (603) 772-0796
www.CHEMTAN.com

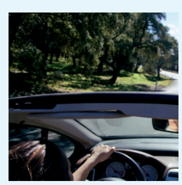
Stahl's innovations driven by sustainability

With the rise of both electric and self-driving, cars are becoming quieter and anti-squeak and rattle materials are becoming increasingly important. At the same time, improved anti-stain performance is required, because of the current trend for pale-colored car seats. Therefore, we have developed Stay Clean. This low-VOC coating technology protects pale-colored leather and vinyl surfaces against common stains, such as dye from jeans, spilled coffee and dirt. Our solution also makes surfaces low-squeak, which is a great asset as global research has shown that a squeaking car interior is one of the biggest annoyances among car owners. Another trend in car interior is the popularity of matt surfaces. Therefore, we have developed PolyMatte®. This non-squeaking solution provides a luxurious feel to the finished article in combination with flexibility and scratch and abrasion resistance. Our portfolio contains many products, varying from beamhouse products, tanning systems to finishes, duller concentrates, crosslinkers and thickeners to leveling agents, defoamers, colorants and hand modifiers. Our most sustainable option is Green PolyMatte®, which is based on rapeseed oil (20%) instead of crude oil-derived intermediates. If you would like to know what our Stahl solutions for automotive can do for your business, please visit **www.stahl.com** or contact us at: **alexander.campbell@us.stahl.com**.

If it can be imagined, it can be created



Stay Clean



Low-VOC

PolyMatte®

stahl

www.stahl.com

Lifelines

Jinwei Zhang, an engineer focused on leather manufacturing and cleaner leather making technology, obtained his Ph. D degree in 2018. He is working at the College of Biomass Science and Engineering, Sichuan University, China. His research interests focus on new and cleaner leather making technology, chrome-free tanning materials and methods, pickle-free tanning methods and leather byproduct utilization. He also helps leather chemical companies and tanneries apply and develop new materials and leather products.

Xiu He, received her Ph.D. degree in Leather Chemistry and Engineering at Sichuan University in 2019. She is working at the College of Biomass Science and Engineering, Sichuan University, China. Her research focuses on cleaner tanning chemicals and technology as well as leather analysis and detection.

Fitsum Etefa Ahmed is a senior researcher and lecturer at Bahir Dar University, EiTEX, since 2015. He is also serving as a Director of Leather Processing and Product Research and Innovation centre at Bahir Dar University, EiTEX, since March 2020 to June 7, 2023. He holds MSc Degree in Leather Product Design and Engineering from Bahir Dar University, in 2018. He served as Leather Engineering Program Head at Bahir Dar University, EiTEX from Sept 2018 tp March 2020. He has mentored total of 28 undergraduate students in data collection and analysis for their BSc Thesis and guided the students in preparation and presentation of research findings since 2015. He has more than 8 published articles in internationally reputable journals.

Aschalew Shitu is a senior researcher and lecturer starting from November 2020 up to Present at Bahir Dar University, School of Animal Science and Veterinary Medicine, Bahir Dar, Ethiopia. He holds Doctor of Veterinary Medicine (DVM) in July 2014 from University of Gondar, Faculty of Veterinary Medicine, Gondar, Ethiopia and Master of Science in Veterinary Parasitology in July 2019 from University of Gondar, College of Veterinary Medicine and Animal Sciences, Gondar, Ethiopia. He has teaching experience starting from October 2019-November 2020 at Debre Tabor University. He has been a graduate Mentor from 2020-2021 at Bahir Dar University, School of Animal Science and Veterinary Medicine, Bahir Dar, Ethiopia, and mentored total of 10 undergraduate students in the graduation Thesis paper writing. He has more than six published articles in internationally reputable journals.

Haile Mekonnen is a senior researcher at Bahir Dar University, department of statistics since 2008. He is the head of the department of statistics at Bahir Dar University. He has served the university as vice dean, department head and course chair. Dr. Haile did his MSc in statistics from Dokuz Eylul university/Turkey and he did his PhD at Bahir Dar University. He has mentored more than 30 undergraduate students, more than 20 MsC and 2 PhD students in his area of specialization. He has more than 40 published articles in internationally reputable journals.

Zerihun Teshome Kebede has been a senior researcher and lecturer at Bahir Dar University, EiTEX, since 2015. He is also serving as a Leather Technology Learning Research and Innovation Team Coordinator at EiTEX from September 2018 until June 2022. He holds his Bsc degree in Leather Engineering from Bahir Dar University in 2017, his MSc Degree in Leather Product Design and Engineering from Bahir Dar University in 2019, and his higher diploma program (HDP) in 2021 from Bahir Dar University. He served as Leather Engineering Program Head at Bahir Dar University, EiTEX, from June 2022 to date. He has mentored a total of 35 undergraduate students in data collection and analysis for their BSc Thesis and guided the students in the preparation and presentation of research findings since 2017. He has more than seven published articles in internationally reputable journals.

Endalamaw Yihune Belay is chief laboratory technician in Botanical Science at Bahir Dar University, Science College. He has completed B.Sc. and M.Sc. degrees in Biology and Botanical Sciences in 2015 and 2018 respectively, from Bahir Dar University, Department of Biology. His thesis on *Antibacterial activity of medicinal plant extracts against Ralstonia solanacearum (Smith) that cause's bacterial wilt in hot pepper (Capsicum annuum L.)* was published in a reputable international journal. Moreover, he has obtained M.Sc degree in Environment and Climate change from Bahir Dar University College of Agriculture and Environmental Science in 2022. He has also attended short term trainings on SPSS, GIS and RS software, and R-software and has acquired knowledge and technical skills of managing/ analyzing data using ANOVA, correlation analysis, PCA, drawing study area maps, receiving data from satellite and interpreting data. He has learned practical knowledge and skills of designing *in vitro*, and field experiments.

Misganaw Bitwe working as an R&D and production supervisor at Bahir Dar Tannery in Ethiopia since 2020. He holds BSc Degree in Chemical Engineering (Leather Technology stream) from Bahir Dar University, in 2018. He has two published articles in internationally reputable journals.

Sadaqat Ali Chattha see JALCA 114, 189, 2019.

Dr. Abdul Rehman was originally trained as a veterinarian, has evolved as an early career veterinary epidemiologist with a strong passion for the epidemiology of infectious diseases of high economic and public health significance. He received his graduation in 2009 and M.Phil in Epidemiology & Public Health in 2012, both with distinction from UVAS, Lahore. Later, he earned PhD degree from Freie Universität, Berlin in 2016. He has won several honors and international awards including DAAD and the Fulbright fellowships and published >40 research articles in top-ranked international journals. He has also won competitive research grants of PKR >30 million and supervised >15 postgraduate students. Currently, he is working on the epidemiology of infectious diseases of livestock including zoonotic infections and AMR-related issues.

Agha Saiddain has more than 35 years of professional experience in the field of leather technology. He is the President of Environment Society of Pakistan Tanners Association and currently serving as Director marketing and operations, Royal Leather Ind. Pvt. He also delivered many lectures at national and international forums on sustainability of leather industry. He is the writer of various articles related to exports, economy and leather sustainability, which have been published in various local and international newspapers and magazines.

Biyu Peng see JALCA 109, 207, 2014.

Yirui Lin received his Bachelor's degree in Light Chemical Engineering from Sichuan University in 2021. Now he is pursuing his Ph.D. degree in Light Industry Technology and Engineering at Sichuan University. His current research focuses on clean leather production.

Zhuocheng Jiang received his Master's degree in Civil & Hydraulic Engineering from Sichuan University in 2023. His research focuses on energy conservation technology.

Ya-nan Wang, see *JALCA* **117**, 127, 2022.

Yunhang Zeng, see *JALCA* **118**, 134, 2023.

Guo Xie is currently an associate professor in State Key Laboratory of Hydraulics and Mountain River Engineering, College of Water Resource & Hydropower, Sichuan University. He received his Ph.D. degree in Power Machinery and Engineering from Beijing Institute of Technology in 2012. He joined Sichuan University as a lecturer from 2014 to 2016 and was an associate professor from 2016 to now. His research focuses on fluid dynamics as well as heat & mass transfer processes.

Bi Shi, see *JALCA* **99**, 220, 2004.

INDEX TO ADVERTISERS

CALL FOR PAPERS

FOR THE 118th ANNUAL CONVENTION OF THE AMERICAN LEATHER CHEMISTS ASSOCIATION

Hershey Lodge, Hershey Pennsylvania
May 21–24, 2024

If you have recently completed or will shortly be completing research studies relevant to hide preservation, hide and leather defects, leather manufacturing technology, new product development, tannery equipment development, leather properties and specifications, tannery environmental management, or other related subjects, you are encouraged to present the results of this research at the next annual convention of the Association to be held at the Hershey Lodge, Hershey Pennsylvania, May 21–24, 2024

Abstracts are due by March 1, 2024
Full Presentations are due by May 1, 2024

They are to be submitted by e-mail to the
ALCA Vice-President and Chair of the Technical Program:

John Rodden
Union Specialties, Inc.
3 Malcom Hoyt Dr.
Newburyport, MA 01950
E-mail: johnrodden@unionspecialtiesinc.com

The **Abstract** should begin with the title in capital letters, followed by the authors' names. An asterisk should denote the name of the speaker, and contact information should be provided that includes an e-mail address. The abstract should be no longer than 300 English words, and in the Microsoft Word format.

Full Presentations at the convention will be limited to 25 minutes. In accordance with the Association Bylaws, all presentations are considered for publication by *The Journal of the American Leather Chemists Association*. They are not to be published elsewhere, other than in abstract form, without permission of the *Journal* Editor. For further paper preparation guidelines please refer to the *JALCA* Publication Policy on our website: leatherchemists.org

Full Presentations are to be submitted by e-mail to the *JALCA* editor:

Steven D. Lange, *Journal* Editor
The American Leather Chemists Association
E-mail: jalcaeditor@gmail.com
Mobile Phone (814) 414-5689


www.CHEMTAN.com
Made with
WATERPROOF
TECHNOLOGY
CHEMTAN
Tel: (603) 772-3741 • Fax: (603) 772-0796 • www.CHEMTAN.com