BG Pulse Journal USA
ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg

EVALUATION OF THE ENVIRONMENTAL AND TECHNOLOGICAL EFFICIENCY OF PLANT-DERIVED SECONDARY RESOURCES IN THE FILLING OF SEMI-FINISHED LEATHER

Professor **M. Shamsieva**, Senior Lecturer **N. Sodiqov**, Master's Student **J. Umarov**
Tashkent Institute of Textile and Light Industry
Doi: https://doi.org/10.5281/zenodo.23239567

Abstract. This study investigated the feasibility of using a plant-derived secondary resource based on pistachio leaves in the filling process of lining leather semi-finished products obtained from sheepskins. The experimental results showed that the proposed composition maintained the main chemical and mechanical properties of the leather at the required level. The use of a local plant resource was evaluated as an alternative to conventional filling agents, and its potential in terms of resource efficiency and environmental performance was substantiated.

Keywords: semi-finished leather, filling, pistachio leaves, secondary plant resource, quebracho, mimosa, environmental efficiency, mechanical properties, lining leather, resource efficiency.

1. INTRODUCTION

Leather manufacturing comprises a multistage, multifactorial and scientifically based sequence of technological operations aimed at converting raw hides and skins into functional materials with high added value. The complexity of these processes is associated with the fact that skin is a natural object with a collagen-based biopolymeric structure and that stability, strength, elasticity, appearance and other required performance properties must be imparted without damaging this structure. Therefore, leather manufacture is regarded as a complex technological system in which chemical reactions, physical transformations and mechanical operations act in an interrelated manner [1].

During pre-tanning operations, unwanted layers and additional biological tissues are gradually removed from the skin structure, while the principal fibrous layer—the dermis—is preserved and brought to a condition suitable for subsequent chemical and technological treatment. The main purpose of these operations is to clean the skin, regulate its natural structure to an appropriate extent and create favorable conditions for efficient tanning. During tanning, the state of collagen, the main structure-forming protein of the skin, is deliberately modified so that the material becomes resistant to external biological effects, putrefaction and mechanical damage. In other words, tanning transforms biological raw material into an industrial leather material with defined performance properties. Post-tanning operations are subsequently used to establish the final quality characteristics of finished leather [2,3]. These operations improve the appearance, surface quality, aesthetic characteristics, physico-mechanical strength, elasticity, softness and other service properties of leather. For this reason, post-tanning treatments are among the decisive technological stages determining the consumer value and functional performance of the finished product.

Among post-tanning operations, filling is of particular importance because it helps minimize the natural non-uniformity occurring in different topographical areas of leather, stabilize quality throughout the entire surface and purposefully tailor its functional properties [4]. As a result, loose and uneven areas are reinforced, the structure becomes more uniform, and important properties such as fullness, density and elasticity are improved. Thus, filling is regarded not only as a means of correcting structural defects, but also as an important stage for imparting additional technological and consumer properties to leather.

In practice, natural and process-related defects such as blood-vessel marks, loose areas, thin zones and regions with a non-uniform fibrous structure may occur in different topographical parts of the skin. Such defects can adversely affect the appearance and service properties of finished leather. Therefore, the use of filling agents to stabilize the leather structure and reinforce non-uniform areas is reported in the literature as one of the most effective technological approaches [5,6]. The essence of the filling process is that specialized chemicals penetrate the fibrous structure of semi-finished leather and occupy the interfibrillar spaces, thereby making the structure more uniform and imparting additional volume, density and fullness. At the same time, such treatment reduces differences among various leather regions, helps stabilize thickness and density, and improves the efficiency of subsequent fatliquoring, dyeing and finishing operations [7,8]. In this respect, filling should not be considered merely as mechanical occupation of voids, but as an important physicochemical stage aimed at developing the structural integrity and functional properties of leather.

The chemical nature, degree of dispersion and technological properties of the substances used for filling are among the major factors determining the final quality of leather [9]. An effective filling agent should, above all, be highly compatible with the fibrous collagen structure of leather, remain stable in an aqueous medium, penetrate deeply into the structure and establish strong physicochemical interactions with collagen fibres. Such agents should be uniformly distributed within loose and non-uniform areas, efficiently occupy interfibrillar spaces and impart the required fullness, density and body to the material. In addition, the composition and properties of the filling agent directly influence subsequent fatliquoring, dyeing and finishing operations. Consequently, the selection of filling agents should take into account not only their filling capacity, but also their ability to purposefully influence the physico-mechanical, hygienic and performance properties of leather.

It should be noted that a wide range of chemical reagents—including chromium salts, sulfides, acids, alkalis, synthetic fillers, resins, formaldehyde-containing compounds, fatliquoring emulsions and dyes—are commonly used during skin processing, tanning, filling, dyeing and fatliquoring [10,11]. A certain proportion of these reagents is not completely taken up during processing and enters wastewater, solid waste and gaseous emissions. This may contribute to air, water and soil pollution, disturbance of ecosystem balance and potential risks to public health. In particular, chromium compounds, free formaldehyde, highly mineralized effluents and organic-load-rich wastes are considered among the major environmental challenges of leather manufacture. Therefore, in recent years increasing attention has been paid to revising the chemical inputs used in the leather industry, reducing their consumption, replacing them with bio-based and less toxic materials, and developing resource-efficient and environmentally sound technologies. This trend has increased interest in local plant raw materials, natural tannins, bio-based fillers and environmentally preferable compositions for leather manufacture.

In the literature, filling agents used in leather processing are generally considered as post-tanning or retanning-filling reagents. Their main functions are to fill loose areas, equalize the structure, impart fullness and density, and improve the effectiveness of subsequent dyeing and fatliquoring stages. Classical sources include vegetable tannins, syntans, resins and acrylic/polymeric fillers in this group, while protein-based and other bio-based filling agents are also used in certain cases [12–14].

In the manufacture of lining leather from sheepskins, filling is one of the most important technological stages governing structural condition, fullness, softness, elasticity and overall performance. It is particularly important for lining leather because this material comes into direct contact with the human body or the inner part of footwear in the final product. Therefore, in addition to adequate strength, lining leather should exhibit softness, structural uniformity, air and water-vapour permeability, a certain moisture-retention capacity and a pleasant handle. The filling stage plays a decisive role in controlling these characteristics and in developing the consumer and hygienic properties of lining leather.

The sensitivity of sheepskin to filling treatment is primarily related to its specific morphological and histological structure. Compared with bovine hides, sheepskin is generally fattier, thinner and softer, with a looser fibre arrangement. Collagen fibres in the dermis form relatively fine bundles and are arranged in a more open and less compact structure. In particular, the papillary layer is well developed in sheepskin, whereas the reticular layer is relatively weaker and finer. Although this provides natural softness and flexibility, it also increases the likelihood of loose zones, non-uniform regions and mechanically weaker areas in the resulting leather.

Considering the histological structure of sheepskin, the principal role of filling is not limited to increasing leather volume. Its primary function is to appropriately occupy interfibrillar spaces, reinforce loose regions of the dermis, reduce non-uniformity between topographical areas and produce a comparatively homogeneous structure across the entire material. Because sheepskin has a naturally looser and softer structure, the selection of filling reagents is particularly important. If a filler produces an excessively harsh effect, the softness and flexibility required for lining leather may decrease; conversely, insufficient filling may leave the leather loose, thin and structurally non-uniform [15].

Another important feature of sheepskin intended for lining leather is the high requirement for air and water-vapour permeability. Owing to its relatively open and loose fibrous structure, sheepskin naturally possesses favorable hygienic properties. To preserve these properties, the filling operation should not excessively compact the structure, but should regulate it to an optimum degree. Thus, in sheepskin lining leather, filling performs a dual function: on the one hand, it reinforces loose and weak regions; on the other hand, it helps retain softness and hygienic properties [16,17].

2. MATERIALS AND METHODS

The study was carried out using semi-finished lining leather produced from sheepskins. In the experimental variant, a plant-derived filling composition based on pistachio leaves was applied, whereas the control variant was treated with conventional quebracho and mimosa extracts. The effectiveness of the variants was assessed comparatively. For chemical evaluation, the moisture content, ash content, chromium oxide content, fatty matter content and pH of the semi-finished leather were determined and compared between the experimental and control variants. Mechanical properties were evaluated in terms of maximum force, elongation at maximum force, stress,

breaking force and elongation at break. The interpretation of the mechanical data took into account the requirements of GOST 940-81 for lining leather and the testing approaches specified in GOST 938.11-69. Environmental efficiency was assessed qualitatively in terms of introducing a local plant-derived secondary resource into beneficial technological use while maintaining leather quality and partially replacing conventional filling materials with an alternative bio-based component.

From this perspective, evaluating the effect of a plant-based filling agent on sheepskin lining leather is of particular scientific interest. Such a filling agent was expected to interact favorably with the naturally loose structure of sheepskin, partially occupy interfibrillar spaces, improve structural uniformity and, at the same time, avoid an excessive loss of softness. Therefore, the technological significance of a pistachio-leaf-based filler in the production of lining leather from sheepskins was assessed by comparing the experimental results with a conventional control. In the control variant, imported vegetable tanning/filling materials—quebracho and mimosa—were used, whereas the experimental variant employed the filler derived from pistachio leaves.

3. RESULTS

The effect of the pistachio-leaf-based filling composition on the quality characteristics of semi-finished lining leather produced from sheepskins was evaluated comprehensively. Experimental samples were compared with the control variant treated with conventional quebracho and mimosa extracts. The chemical composition, pH and subsequent mechanical properties of the semi-finished leather were selected as the principal evaluation criteria. First, the main chemical characteristics of the experimental and control samples were analyzed to determine the influence of the filling composition on the chemical condition of the leather. The results are presented in Table 1.

Table 1

Chemical characteristics of semi-finished lining leather samples obtained from sheepskins

	Variants	
Parameter	Experimental	Control
Moisture content – mean value, %	11.1	12.2
Ash content – mean value, %	5.0	5.5
Chromium oxide content – mean value, %	4.11	4.13
Fatty matter content – mean value, %	10.0	7.5
Mean pH value	4.900	4.600

As shown in Table 1, the pistachio-leaf-based filling composition was used in the experimental variant, while the control variant was treated with conventional vegetable tanning/filling agents—quebracho and mimosa extracts. The principal chemical characteristics of the experimental leather were close to those of the control. Specifically, the experimental sample had a moisture content of 11.1%, ash content of 5.0%, chromium oxide content of 4.11% and pH of 4.9, compared with 12.2%, 5.5%, 4.13% and 4.6, respectively, for the control sample.

At the same time, the fatty matter content of the experimental sample was 10.0%, which was higher than the 7.5% observed in the control. Overall, the use of the pistachio-leaf-based filling composition did not cause substantial changes in the main chemical characteristics of the semi-

finished leather and provided results comparable with those obtained using the conventional quebracho- and mimosa-based treatment. This indicates the feasibility of using the pistachio-leaf-derived composition as an alternative local raw material in the leather filling process.

Mechanical characterization was also important for evaluating the effect of the pistachio-leaf-based filling composition on leather properties, because the interaction of filling agents with collagen fibres directly affects leather strength, extensibility and deformation behaviour. Therefore, the breaking force and elongation characteristics of the experimental samples were determined and their mechanical properties were evaluated. The results are shown in Figure 1.

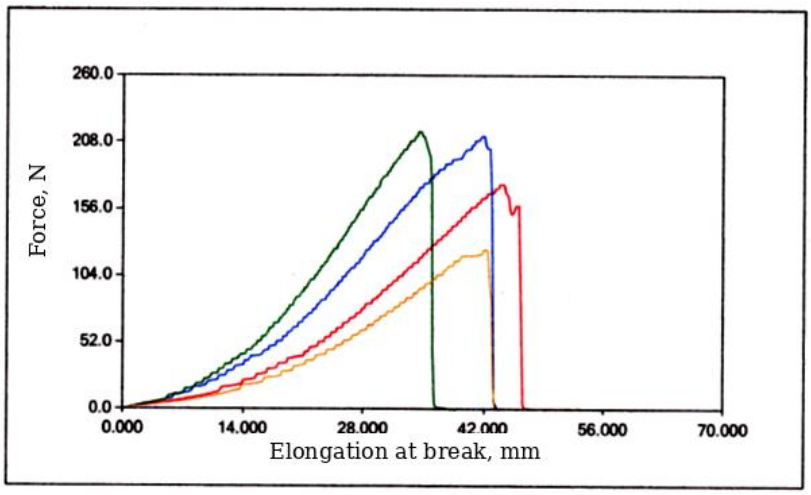


Fig. Mechanical characteristics of leather filled with the pistachio-leaf-based composition

Fig. presents the force–elongation-at-break relationships obtained from tensile extension tests of the leather samples. The horizontal axis represents elongation at break (mm), while the vertical axis represents the applied force (N). For each sample, the force gradually increased until a maximum value was reached, after which rupture occurred. The resulting curves characterize the elastic-plastic behaviour, tensile resistance and deformation capacity of the leather samples. The diagram indicates that the samples possessed satisfactory mechanical strength together with adequate extensibility.

Table 2

Mechanical test results of the leather samples

No.	Colour	Sample	Maximum force, N	Elongation at maximum force, mm	Stress, MPa	Breaking force, N	Elongation at break, mm
1		Sample No. 1	175.300	43.94	8.765	0.70	47.63
2		Sample	213.100	41.87	10.655	6.70	43.25

		No. 2					
3		Sample No. 3	216.200	34.69	10.810	0.70	37.86
4		Sample No. 4	124.300	42.29	6.215	0.10	61.77
		Mean	182.225	40.70	9.111	2.05	47.63
		Standard deviation	42.860	4.10	2.143	3.11	10.24
		Maximum	216.200	43.94	10.810	6.70	61.77
		Minimum	124.300	34.69	6.215	0.10	37.86

The test results presented in Table 2 allow a comprehensive assessment of the mechanical properties of the leather samples. The main parameters determined for each sample included maximum force, elongation at maximum force, stress, breaking force and elongation at break, which characterize tensile resistance, flexibility and deformation capacity. The mean values were 182.225 N for maximum force, 40.70 mm for elongation at maximum force, 9.111 MPa for stress, 2.05 N for breaking force and 47.63 mm for elongation at break. These values indicate that the leather samples possessed sufficient mechanical strength together with relatively good deformability. Their ability to withstand comparatively high loads and undergo considerable extension before rupture suggests that the material can retain flexibility and comfort under service conditions, particularly when used as lining leather.

4. DISCUSSION

Comparison of these results with the requirements of GOST 940-81 for sheepskin lining leather further clarifies their practical significance. According to this standard, lining leather should have a moisture content of 10–16%, a content of substances extractable with organic solvents of at least 3.7%, a thickness of 0.6–1.2 mm, and an elongation at 10 MPa in the range of 15–40%; adequate tensile strength is also required as a key mechanical characteristic. The standard specifies that mechanical properties should be determined in accordance with GOST 938.11-69, which is used to assess tensile strength, elongation at 10 MPa and deformation at break.

The mean mechanical data in Table 2 show that elongation at maximum force was 40.70 mm, indicating a high deformation capacity of the leather. This is advantageous for lining leather because the material is continuously subjected to bending, friction and pressure during service. Relatively high elongation therefore supports the ability of the leather to retain its service stability and developed handle. In addition, the tensile strength indicator was reported as 1.0, which is above the minimum requirement of 0.8 specified by GOST 940-81. Thus, the test results confirm that the leather meets the relevant mechanical strength requirement.

The mean stress value of 9.111 MPa also indicates satisfactory resistance of the leather samples to tensile loading. This value reflects the mechanical stability developed as a result of the natural fibrous structure and the applied technological treatment. In sheepskin lining leather, where the natural dermal structure is relatively loose, filling and other post-tanning operations are

particularly important for stabilizing mechanical properties. Therefore, an average stress value above 9 MPa suggests that filling and subsequent post-tanning treatments were effective in these samples.

The mean elongation at break of 47.63 mm indicates that the material developed sufficient plastic deformation capacity. This is especially important for lining leather, which must be not only strong but also flexible enough to accommodate movement during wear. The standard deviations—42.860 N for maximum force, 4.10 mm for elongation at maximum force, 2.143 MPa for stress, 3.11 N for breaking force and 10.24 mm for elongation at break—indicate a certain natural variability among the samples. Such variability is characteristic of natural collagenous materials such as leather and can arise from differences in topographical sampling location, fibre orientation and local density. Despite this variability, the stability of the mean values confirms the satisfactory overall mechanical quality of the samples.

From an environmental perspective, the results indicate that introducing a plant-derived secondary resource such as pistachio leaves into the leather filling stage is consistent with the principle of valorizing waste or low-value biomass streams.

5. CONCLUSION

The study demonstrated that a pistachio-leaf-based filling composition can be technologically suitable for the filling stage in the manufacture of sheepskin lining leather. The proposed composition enabled the required fullness, strength and deformation characteristics to be maintained without an adverse effect on the collagen fibrous structure. The similarity of the chemical and mechanical characteristics of the experimental samples to those of the control confirms the potential of the pistachio-leaf-derived composition as an alternative to conventional vegetable-based filling agents.

The practical significance of the study lies in integrating a local plant-derived secondary raw material into leather processing. This approach can contribute to the valorization of waste or underutilized biomass, partial reduction in the consumption of imported plant-based materials and more rational use of resources in leather manufacture. Accordingly, the pistachio-leaf-based filling composition can be considered a promising component for the development of environmentally oriented and resource-efficient leather technologies.

REFERENCES

1. Maina P, Ollengo MA, Nthiga EW (2019) Trends in leather processing-a review. Int J Sci Res Publ 9:9626. https:// doi. org/ 10. 29322/ ijsrp.9.12. 2019. P-9626.
2. Thanikaivelan P, Rao JR, Nair BU, Ramasami T (2005) Recent trends in leather making: processes, problems, and pathways. Crit Rev Environ Sci Technol 35:37–79. https:// doi. org/ 10. 1080/ 10643 38059 05214 36.
3. Muralidharan V, Palanivel S, Balaraman M (2022) Turning problem into possibility: a comprehensive review on leather solid waste intra-valorization attempts for leather processing. J Clean Prod 367:133021. https:// doi. org/ 10. 1016/j. jclep ro. 2022. 133021.
4. Yorganicioglu A, Basaran B, Sancakli A (2020) Value addition to leather industry wastes and by-products: hydrolyzed collagen and collagen peptides. INTECH i:13.

5. Taylor MM, Lee J, Bumanlag LP et al (2009) Treatment of low-quality hides with fillers produced from sustainable resources: effect on properties of leather. J Am Leather Chem Assoc 104:324–334
6. Li Y, Guo R, Lu W, Zhu D (2019) Research progress on resource utilization of urban sludge. J Leather Sci Eng 361–363:934–937. https://doi. org/ 10. 4028/ www. scien tific. net/ AMM. 361- 363. 934.
7. Taylor MM, Bumanlag L, Marmer WN, Brown EM (2006) Use of enzymatically modified gelatin and casein as fillers in leather processing.J Am Leather Chem Assoc 101:169–178
8. Liu X, Yue O, Wang X et al (2020) Preparation and application of a novel biomass-based amphoteric retanning agent with the function of reducing free formaldehyde in leather. J Clean Prod 265:121796. https:// doi. org/ 10. 1016/j. jclep ro. 2020. 121796
9. Danylkovych AH, Korotych OI (2019) Optimization of leather filling composition containing SiO2 nanoparticles. J Am Leather Chem Assoc 114:333–343.
10. Leather RR. Ullmann's encyclopedia of industrial chemistry. Weinheim: Wiley-VCH Verlag GmbH & Co. KGaA; 2015. p. 621–63.
11. Covington AD. Post tanning. In: Leather Processing II. Northampton: The University of Northampton; n.d. p. 1–23. Website: EOPCW. Accessed: 03.05.2026.
12. Leather Naturally. Modern cow leather processing. Part two. 2023. 44 p. Main sections: p. 9–10, 24–31. Website: Leather Naturally. Accessed: 03.05.2026.
13. Yusuf A. Post tanning operation. In: Leather Processing II. 2020. p. 1–18. Website: EOPCW. Accessed: 03.05.2026.
14. Jankauskaite V, Jiyembetova I, Gulbiniene A et al (2012) Comparable evaluation of leather waterproofing behaviour upon hide quality. I. Influence of retanning and fatliquoring agents on leather structure and propeties. Mater Sci 18:150–157. https:// doi. org/ 10. 5755/ j01.ms. 20.2. 2339.
15. Matos JC, Menezes VG, Gois GC, Araújo GGL, Barcellos BSC, Soares MG, Matos MHT, Moraes EA, Menezes DR, Queiroz MAA. Histological and physical-mechanical characteristics of the skin of Dorper sheep related to residual feed intake and the confinement environment. Tropical Animal Health and Production. 2022;54:314. DOI: 10.1007/s11250-022-03320-6. Available from: Springer Nature. Accessed: 08.05.2026.
16. Gogaev OK, Demurova AR. Topographic features of sheep skin and coat structure. Journal of Livestock Science. 2021;12:141–146. Available from: Journal of Livestock Science. Accessed: 08.05.2026.
17. Fourneau M, Canon C, Van Vlaender D, Collins MJ, Fiddyment S, Poumay Y, Deparis O. Histological study of sheep skin transformation during the recreation of historical parchment manufacture. Heritage Science. 2020;8:78. DOI: 10.1186/s40494-020-00421-z. Available from: Springer Nature. Accessed: 08.05.2026.