ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 9, September 2024

Effect of furfural on physical-mechanical and chemical properties of leather

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ABSTRACT. In this study, the effect of furfural on the physical-mechanical and chemical properties of natural leather was studied, tanned leathers treated with furfural tanning agent achieved high hydrothermal stability, strength, and elongation at break indicators, and furfural-treated tanned a large horned cattle leathers obtained complex properties.

KEYWORDS: furfural, tanning, leather, hydrothermal, destruction, complex properties and degree of improvement.

I. INTRODUCTION

In the world, scientific research is being conducted aimed at improving the technology of processing raw materials of bighorn cattle. In this direction, among other things, scientific research on the creation of tanning agents that provide complex chemical, physicomechanical, and hygienic properties to the morphological structure of cattle leather and their use in the technology of tanning agents is considered a priority. Therefore, reducing the amount of toxic chromium compounds, using alternative materials, and creating technologies that serve to improve product quality and increase production efficiency are urgent tasks.

To a certain extent, this article is related to the implementation of the tasks defined in the Decree of the President of the Republic of Uzbekistan No. PF-60 of January 28, 2022 "On the Development Strategy of New Uzbekistan for 2022-2026", No. PD-3603 of March 14, 2018 "On Measures for the Rapid Development of the Leather and Pearl Industry", Decision PD-2718 of January 6, 2017 "On measures to expand the sources of financing of investment projects in the food, leather-shoe, and pharmaceutical industry" and other regulatory legal documents related to this activity.

Leather production is based on the technology of treating leather with high-concentration chemical materials in aqueous solutions with mechanical action.

Many years of experience in the production of collagen-containing raw materials, despite the availability of technological solutions, are associated with the consumption of large amounts of water, the discharge of wastewater into virgin, freshwater bodies, and decisive changes are still not taking place. Fundamental changes in the solution of environmental problems consist only in the creation of new technologies of fluid treatment or other.

At the moment, due to environmental problems, the environmentally friendly "Green leather, fur" is limited in the amount of chromium, especially salts of heavy metals, and the amount of waste should be minimal. Different countries have different wastewater standards.

Chromium-plated leather and fur contain less toxic III-valent chromium, which is currently approved for use. However, in dealing with liquid sewage or solid waste, compliance with existing laws and regulations is required [1].

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One of the serious problems is the recycling, treatment, storage, and utilization of chromium-containing wastewater and waste. To overcome the technical and environmental problems caused by the traditional addition of chromium, there are various approaches such as modification of chromium tanning agent, combined tanning agents, use of collagen as adjuvants, as well as improvement of chromium tanning agent parameters [2-3].

Among these alternatives, in recent years, chromium plating technology has been conducted initially at lower pH values and then completed at higher values. However, the same technology is not directly applied in the industry, because there are potential risks due to the initial high values of rN forming a precipitate on the surface of the leather, not being fully absorbed into the dermis layer, and changing the quality of the finished product. It is worth noting that instead of the traditional existing chrome plating, new developments are being created by the world's leading companies based on various research and experiments to optimize industrial processes in the laboratory and semi-production scales of the leather-fur industries, to preserve the analog properties and quality of the product [4].

At the same time, mineral processing causes environmental pollution, especially in developing countries. Thus, a non-mineral casting process should be used to maintain sustainable leather production [5].
However, the chromium (III) compound used in tanning also contains chromium (VI), which naturally poses a risk to human health and harms the environment [6].

Chromium compounds are also widely used due to their unique properties compared to vegetable, oil, synthetic, and other tanning materials because chromium tanning provides leather with better performance compared to other tanning agents [7].

Although chrome disposal methods are well known, the leather-fur industry still faces these problems. Chromic wastewater reduces soil fertility and prevents the development of local flora [8].

As a result of the results of comparative studies [9-10], it was noted that the properties of thermostability and strength indicators of cattle leather tissue treated with the experimental tanning agent were significantly improved.

However, prepared Wet-green leather has hydrothermal destruction at 100°C and good abrasion [11]. However, the use of drugs by foreign companies in the technological processes of leather production not only increases the cost of the manufactured product but also creates organizational, technical, economic, environmental, and sanction risks.

One of the most ancient processing methods in the production of such cattle leather is aluminum and raw leather tanning (rawhide). In this method, the reverse side of the leather becomes white. Extreme tensile strength occurs in the presence of aluminum salts and formalin [12]. There is also information on the application of the above-mentioned titano-aluminum coating [13].

Currently, chrome-plated leather contains less toxic III-valent chromium, which is currently approved for use. However, in dealing with liquid sewage or solid waste, compliance with existing laws and regulations is required [14]. However, furfural tanning is a complete substitute for chromium tanning and its toxicity should be thoroughly studied to accept it as an environmentally friendly tanning. The types of tanning of the bighorn cattle leather with furfural tanning were developed exactly as a replacement for chromium.

Although chrome disposal methods are well known, the leather-fur industry still faces these problems. At the moment, the method of tanning leather with chrome is widespread in the world, and there is no practice of tanning with furan compounds specifically for leather. As an example of high molecular compounds that meet today's requirements, we can cite furfural compounds. Because the furfural compound is obtained from various agricultural wastes (sunflower stalks, straw, and bran), it is extracted with sulfuric acid, as well as by boiling wood.

Furfural is an organic compound, the chemical formula of furfural is $C_5H_4O_2$. Clear and colorless liquid, easily soluble in water, causes lung and eye irritation.

One of the main problems in the leather industry is the shortage of chemicals used in advanced leather processes. This leads to an increase in the cost of purchasing chemicals in foreign currency transportation costs and the cost of leather produced in Uzbekistan. Chromium tanning in leather processing is more universal than other tannings and gives better chemical and physical properties to leather [15]. The dermal filler diffuses through different layers of the tanning leather. This can cause chromium compounds to spread unevenly across the layers of the leather, reduce plasticity, and tear strength, and stretch across the area.

II. RESULTS AND DISCUSSION

To compare the physico-mechanical and chemical properties of leather, leathers of the same type were selected and tanning processes were carried out for control and experimental variants. Here, in the experimental version: liquid coefficient (LC) - 0.7 liquid temperature - 25 ºC, basicity 36-42% and furfural additive - 2.5%, NaCl (salt) - 4.5%, chromium tanning - 0.5 %, was treated with chemical reagents for 12 hours and the tanning process was carried out until the hydrothermal destruction exceeded 100 ºC. All other processes were carried out according to the traditional method. The effectiveness of the tanning process was evaluated by changing the hydrothermal chemical and physical-mechanical indicators of the leather tissue and the finished product.

The technological processes of processing bighorn cattle leathers were carried out according to the following scheme:

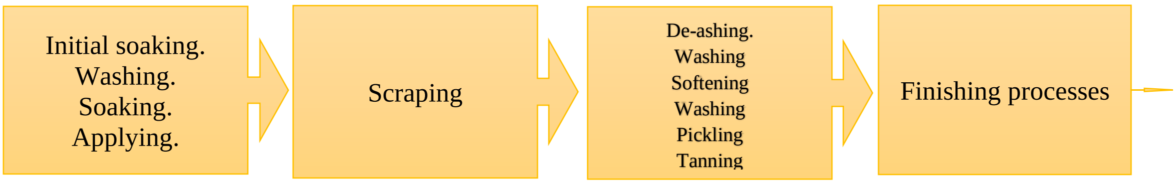

Figure 1. Scheme of technological processes of processing bighorn cattle leathers.

The next turn of these studies was focused on the study of the physico-chemical properties of bighorn cattle leathers and finished products. The formation of the properties of leather, their quality, and their quantitative values are mainly determined by the type and nature of chemical materials. Currently, we use furfural and salt in our experimental samples to add such chemical materials to cattle leathers. For our control samples, based on existing technology, chemical materials such as chromium enhancer, and sodium carbonate were used.

It should be noted that all listed chemical materials are liquid, dissolved, and have other states of aggregation. However, the physico-chemical properties of the produced leather must meet the requirements of GOST. Therefore, taking into account the above, the experiments were carried out and the results were presented by taking samples of the standard fields of fur for testing the main physico-chemical parameters of the experimental and control samples (Table 1).

Table 1.
Dependence of the consumption of different tanning agents on the physicochemical properties of a bighorn cattle leather

№	Samples	The amount of minerals, %	Fat content, %	Moisture content, %
1	a	6,9835	8,12	13,09
2	b	7,1287	9,01	13,17
GOST 939-2021		Not less than 3,5	4,0-16,0	10,0 - 16,0

Here a is an experiment and b is a control sample.

As can be seen from these results, the moisture content of the samples is almost the same, the amount of fat content is 8.12% in the experimental sample and 9.01% in the control version. The amount of mineral substances in leather is 6.9835% in the experimental sample and 7.1287% in the control sample. These indicators were compared to GOST 939-2021, checking their reliability, and we witnessed that all indicators corresponded.

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Continuing this research work, the hydrothermal destruction temperature, which is one of the main indicators that quantitatively describes the tanning process, was determined based on a known method and the results are presented in the table.

Table 2
Hydrothermal destruction of large horned cattle leather on a standard plot

Samples	Hydrothermal destruction, **°C**
a	116
b	113
GOST 939-2021	Not less than 100

Here a is an experiment and b is a control sample.

When comparing the control and experimental samples of large horned cattle leather, the hydrothermal destruction temperature of the experimental sample treated with furfural tanning was 116 °C, and it was found to be 113 °C in the control sample. From the result, it can be seen that the experimental sample is 3 oC higher than the control sample.

It is known that hydrothermal destruction is one of the main indicators that describe the degree of improvement of leather, and this indicator changes in each process. To study the importance of the processes in leather production, the effects of leather added with furfural and leather added with chromium on hydrothermal destruction were studied. In this case, grade II, moderately defective cattle leather was selected and divided into two parts from the spinal area, samples were processed according to technology in traditional and experimental methods. The kinetics of changes in the hydrothermal destruction of big horn cattle leather depending on the processes are shown in Fig. 2.

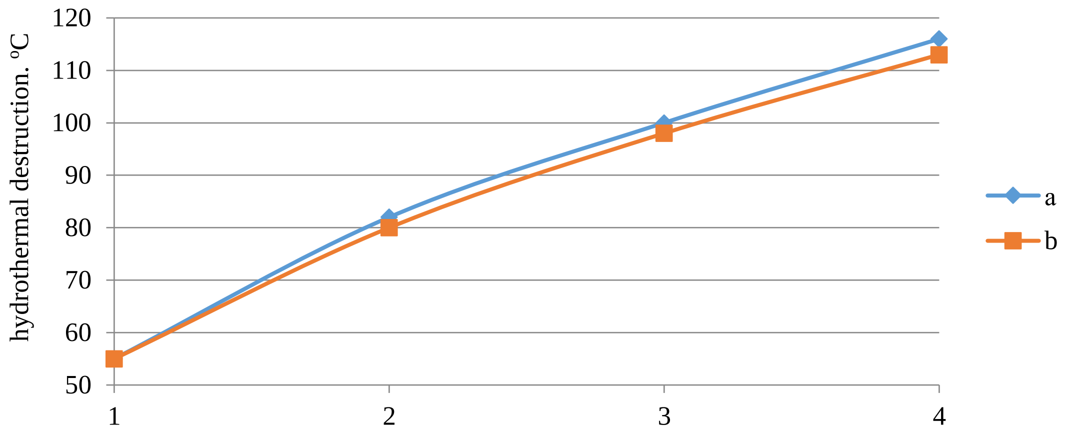

Figure 2. Variation of hydrothermal destruction of a-experimental and b-control sample depending on the processes. Here it is 1st pickled, 2nd after tanning, 3rd after 24 hours of laying, 4th before painting.

As can be seen from the graph, the influence of the heating process on hydrothermal destruction is becoming more important. In this case, the hydrothermal destruction temperature in the experimental and control samples was respectively a-55 °C, b-55 °C in the 1st area, a-82 °C, b-80 °C in the 2nd area, a-100 °C, b-98 °C in the 3rd area, and the 4th area, it is a-116 °C, b-113 °C. We can conclude that we once again witnessed that the main process that serves to improve hydrothermal destruction in leather processing processes is the process of tanning and laying.

Because one of the main indicators for evaluating the quality of the produced leather is its strength and elongation at break. Naturally produced leather is required to be strong and elastic. Therefore, the elongation at break of the control and experimental samples of the enhanced leather, as well as the strength limits, were determined using a Japanese WDW-5E breaking machine, while standard samples were cut. For this, experimental and control samples were selected, and to increase the accuracy of the results, 4 standard samples were cut from each sample, and the average value of the results is presented in Figure 3.

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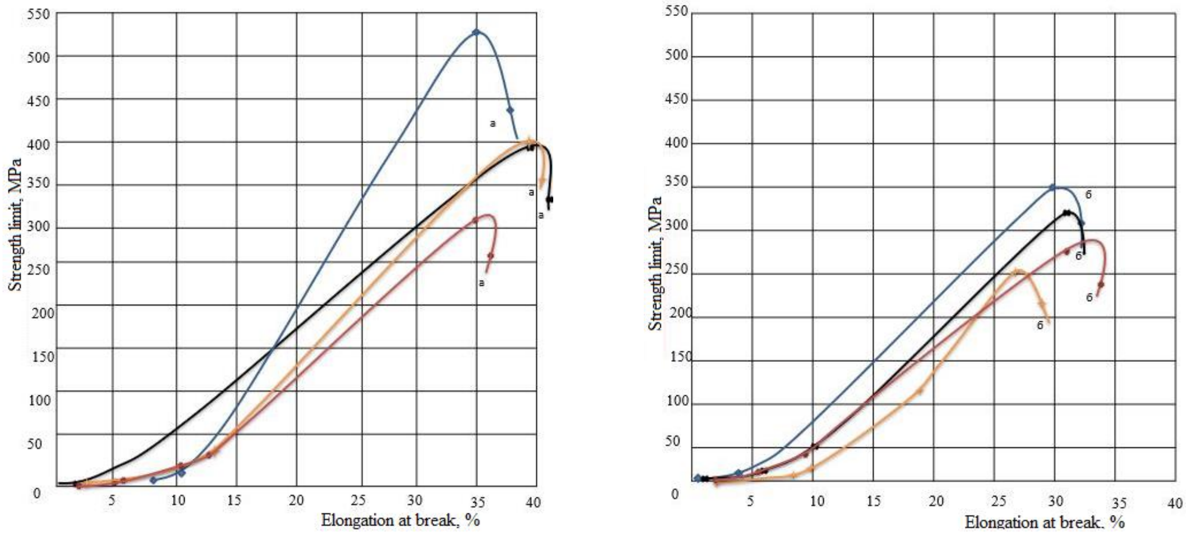

a b

Figure 3. Graph of relationship between tensile elongation and strength limit of a-experimental and b-control samples.

In this case, the average value of elongation at the break of the test-a sample was 70.6% and the strength limit was 52.4 MPa. In the control-b sample, the average elongation at break was 61.6%, the strength limit was 42.3 MPa, and these results were found to be by GOST 939-2021 based on experimental tests.

Based on the above results, we can conclude that furfural, giving softness to the leather, improved its elongation at break, and other tanning substances included in the composition of the derma also showed a positive effect on hydrothermal destruction and strength limits by forming complex bonds in the dermis.

III. CONCLUSIONS

Thus, the possibility of using furfural tanning for tanning bighorn cattle was studied for the first time. Physico-mechanical and chemical properties of cattle leather were determined, and the results were cited and discussed. The results found that the amount of fat, mineral substances, and moisture in the samples is under GOST 939-2021, and hydrothermal destruction is 116 ^oC in the experimental sample and is 113 ^oC higher than the control sample. According to the results of the analysis of the dependence of hydrothermal destruction on the processes, it was found that the highest indicator belongs to the process of increase. It was found that the tensile strength and elongation at break, which are one of the main indicators of leather, were 10.1 MPa and 9% higher in the experimental sample than in the control sample, respectively.

By comparing the results of physico-mechanical tests, it was noted that leathers treated with furfural tanning have high hydrothermal stability, strength, and elongation at break indicators. From the results, it can be concluded that furfural-treated leathers of large horned cattle have complex properties.

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