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# Research of the influence of laser modification on the physical-mechanical properties of Wet-Blue leather semi-product

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**ABSTRACT**. The effect of laser modification on the physical and mechanical properties of the Wet-Blue leather semi-product was studied, and general information on sheepskin processing, skin weight and area, and wool color was given. Information on the Wet-Blue leather semi-product, the results of research on the treatment of leather tissue by various physical methods, as well as laser technology and its effect on the skin tissue, and the scheme of the proposed modified Wet-Blue leather semi-product manufacturing process scheme are presented. To compare the experimental test results with each other, two standard sheepskin raw materials of the same grade were selected, and these skins were processed based on the traditional and proposed technological sequence. Using these methods, the results were obtained on the standard sections of leather semi-products and compared with each other. During the study, process-dependent changes in hydrothermal destruction and the results of strength limit and elongation at break were determined through experimental tests.

**KEYWORDS:** Laser irradiation, wavelength, laser energy, wet-blue, chromium tannin, tanning, scraping, hide, collagen, epidermis, skin tissue, hydrothermal destruction, fat, moisture, tensile strength, relative elongation

## I. INTRODUCTION

Leather industry materials are products of chemical processing of biological raw materials. Their main component is supramolecular complexes of fibrillar proteins. Collagen is the basis of leather structure. Collagen has a highly ordered structure and forms complexes of fibrous leather structures.

Tanning is a key process in the leather manufacturing process of treating the collagen fiber structure of the leather, mainly with a tannin (a type of cross-linked protein), which transforms decaying untreated hides into durable leather that can withstand thermal, enzymatic, and microbial effects [1].

Wet-Blue refers to an intermediate step in the process of treating leather raw materials with chromium salts, in which the hides are only chromed, wet, and blue in color [1].

Chromium salts are the only tannins because they create the most necessary properties of leather [2].

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Currently, the problems of improving the quality of leather products are urgent. Requirements for the quality of leather raw materials include not only strength properties but also appearance. Product quality can be improved by creating new materials or by modifying them using non-traditional physical methods to give new properties [3].

In the production of Wet-Blue leather semi-finished products, the use of cyclic carbonates and products based on them in chrome-saving technology increases the amount of irreversibly bound chromium, and the possibilities of accelerating the process of chrome addition while maintaining the time and concentration parameters, as well as the properties of the semi-finished product, have been studied [4].

Plasma treatment of Wet-Blue leather raw materials in the production technology of chromium-enhanced semi-products has been found to cause morphological changes in the molecular surface structure of collagen, which is manifested in the enlargement and division of fibrils and fibers in the raw material, and in the division of fibers and tufts in the leather tissue and semi-products [5].

The high efficiency of the process of chrome tanning of the skin using ultrasound has been shown. A description of the growth technology was given, and the new process allowed to reduce the time required for growth and obtain a higher quality material [6].

One of the new promising areas of Wet-Blue leather semi-product modification is its laser light treatment. The advantage of this method is that it allows to radically change the structure of fibers [7].

The main physical parameters of the laser effect on natural skin are its wavelength, power, and density [8,9].

Under the influence of the first laser impulse, the water molecule in the skin structure evaporates, the temperature rises in the layer near the surface, and an area of reduced air pressure density is formed, which leads to a more complete use of the energy of the second impulse for laser ablation [8].

## II. MATERIALS AND METHODS

In the research, sheep skin tissue samples were treated with a laser in double impulse mode.

During research LS-2134D (LOTIS, Belarus) aluminoittrium grenade generated a two-impulse mode with a wavelength of 1064 nm (impulses were separated by a time interval of 3 ms, and impulse duration was 10 ns). Samples were processed by exposure for 10-40 seconds at energy intervals of 10-30 J [10].

There are several dozen breeds of sheep, which are divided into 4 groups: short-tailed, skinny-tailed, fat-tailed, and rumpled. Sheep skins differ greatly depending on the breed, age, and season of preparation. The epidermis of sheepskins is thin, making up 1,8–2,5 % of the skin thickness. The leather pattern consists of fine, evenly-spaced pores and has a very smooth surface. The nodular and reticular layers of the dermis have a clear border, and the thickness of the nodular layer is greater than that of the reticular layer. In coarse-wool sheep, the hair is deep in the dermis, the nodular layer of the dermis is 70-80 %, and in wool sheep, it is 50%. The nodular layer contains many soft hair follicles, sebaceous and sweat glands, and hair-raising muscles. The collagen bundles of the mesh layer of sheep skins are thin, less dense than other animal skins, and wrinkled horizontally. Desert sheep are larger than Russian sheep, their skin area is 70-85 $dm^2$. The amount of fat is quite large, mainly nodular, and located at the border of different layers. Desert sheep skins are used for the production of chevret and sheepskin. Low-quality sheepskins are used for lining leather, and leather for gloves and footwear [11].

Wet-Blue represents a quantitative description of the heat and moisture tolerance of the leather semi-finished product structure. The hydrothermal destruction temperature varies depending on the heating method, filling, and finishing processes. As the acid content of the Wet-Blue leather semi-product increases, the ripening temperature decreases, while the higher the division and porosity of the skin tissue microstructure of leather and fur, the lower the temperature of hydrothermal destruction.

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Hydrothermal destruction refers to the temperature at which the size of the skin texture or semi-finished product sample of leather and fur to be tested begins to change, that is, to decrease.

For the experiment, a 60×3 mm sample was first cut, stored 10 times its weight in distilled water at room temperature for 18 hours, and then its two ends were pierced with a thick needle.

If the hydrothermal destruction of the tested sample is below 100 $^{o}$C, distilled water was poured into the container, if it was above 100 $^{o}$C, a mixture of glycerin and water in a ratio of 80:20.

The liquid in the vessel was heated at a rate of 2 $^{o}$C per minute. The temperature was determined at the minute the scale moved. The average arithmetic value of the results of the tests conducted for two samples, reaching the temperature of hydrothermal destruction, was accepted. The deviation between the two parallel tests did not exceed 2 $^{o}$C [12].

Determination of the elasticity of the Wet-Blue leather semi-product was carried out on a Japanese WDW-5E stretching machine. For this, a sample is cut as shown in Figure 1. The ABCD area is the working area. AB- length, AD, and BC width.

When testing Wet-Blue leather semi-finished products, samples with a length of 50 mm and a width of 10 mm are usually used. 4 samples are cut for the experiment. Before starting work, the working area of the sample is divided into five parts, marked from one to five. The thickness of each marked area is measured.

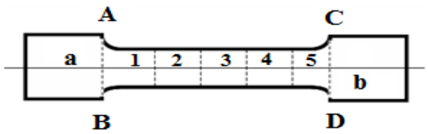


*Figure 1. The shape of the test specimen for breaking the specimen.*

After the machine starts, the upper clamp moves up and pulls the lower clamp through the sample. As a result, the sample becomes longer. The movement of the clamp creates a force corresponding to the stretch. When the voltage increases, the sample breaks.

The system of data management and collection in the machine is based on a modern personal computer. The control program outputs all measured and calculated parameters, as well as load diagrams set in different coordinates in a real-time [13].

## III. RESULTS AND DISCUSSION

Taking into account the above-mentioned research work, we set ourselves the task of using a new generation laser technology that gives complex properties to the Wet-Blue leather semi-product. Laser technologies are not widely used in the production of leather products. Laser irradiation has coherence monochromaticity collimation, which is its peculiarity. The interaction of laser irradiation with skin tissues is based on its physical properties [8].

When the skin tissue is modified with laser light, obtaining one or another effect depends on the selected processing mode. The quality of raw materials and processing processes have a significant impact on the quality of Wet-Blue leather semi-finished products.

Therefore, the main task is to choose optimal parameters of laser irradiation that allow maximum absorption of chemicals into the skin tissue.

In addition to the traditional technology of Wet-Blue leather semi-finished product production, laser irradiation was introduced, and the scheme of this technological process is shown in Figure 2 below.

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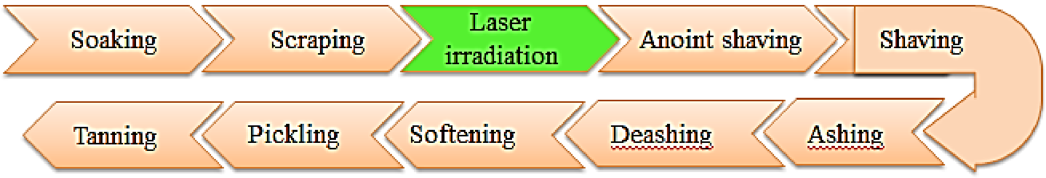


*Figure 2. Wet-Blue leather semi-finished product production technological process scheme*

The use of laser irradiation treatment before the tanning process leads to an additional separation of fibers of the dermis structure and an increase in the number of available functional groups of collagen that react with chromium complexes and radicals. Such a modification of the skin helps to accelerate the distribution of chemicals, in particular, the enhancer, to the leather tissues in the subsequent processes, as well as to reduce the amount of binding, the duration of the process, and a more intensive and orderly restructuring of the Wet-Blue leather semi-product.

The samples of sheep skin that have undergone the process of scraping were treated with laser radiation in the range of 15-30 J energy with an exposure time of 10-40 seconds.

The most effective methods of researching the samples treated with laser beams were determined by the hydrothermal destruction of leather raw materials. These parameters showed that laser modification led to morphological changes in the structure of the dermis.

When skin raw material is irradiated with laser in different modes, the supramolecular structure of collagen changes by 4.3 % in the destruction temperature due to the breakdown of weak intermolecular chemical bonds (Fig. 3), which confirms the morphological changes in the structure of skin raw material.

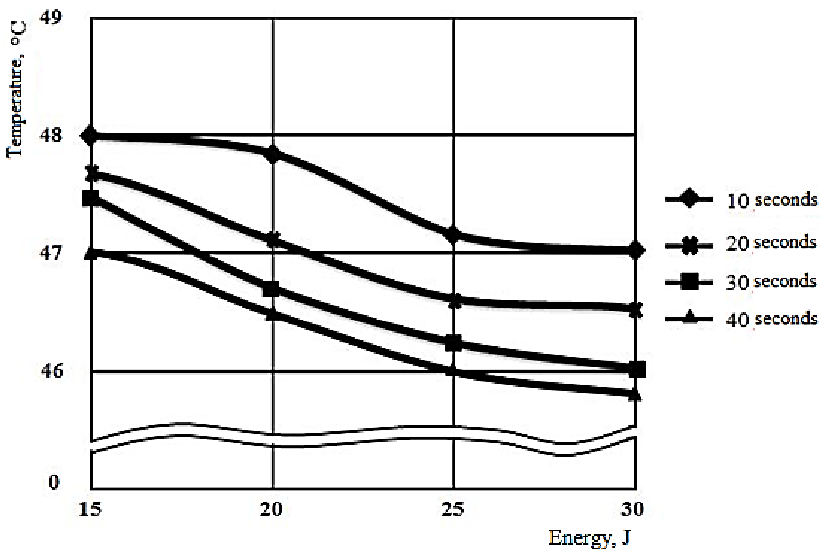


*Figure 3. – Changes in the hydrothermal destruction of laser-treated scraped sheepskin samples.*

The tanning process is important in leather production, as it transforms rapidly decomposing raw hides into stable leather that can withstand thermal, enzymatic, and microbial effects [1].

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The quality of the tanning process is evaluated by the hydrothermal destruction of the Wet-Blue leather semi-finished product. Hydrothermal destruction of samples of laser-modified Wet-Blue leather semi-finished products in different modes is presented in Fig. 4. Hydrothermal destruction of sheep Wet-Blue leather semi-product reached -95 °C in the control sample and up to 98 °C in the experimental samples.

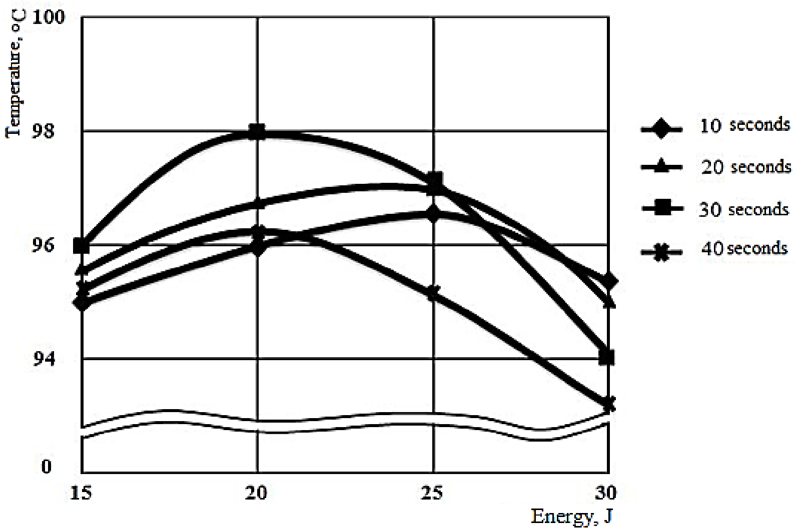
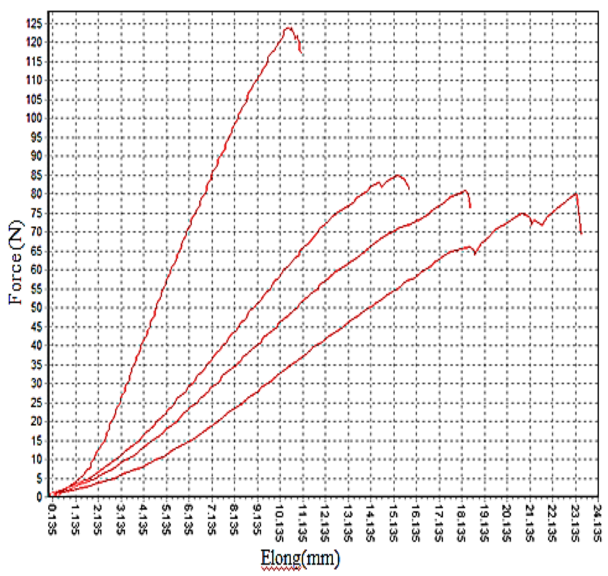


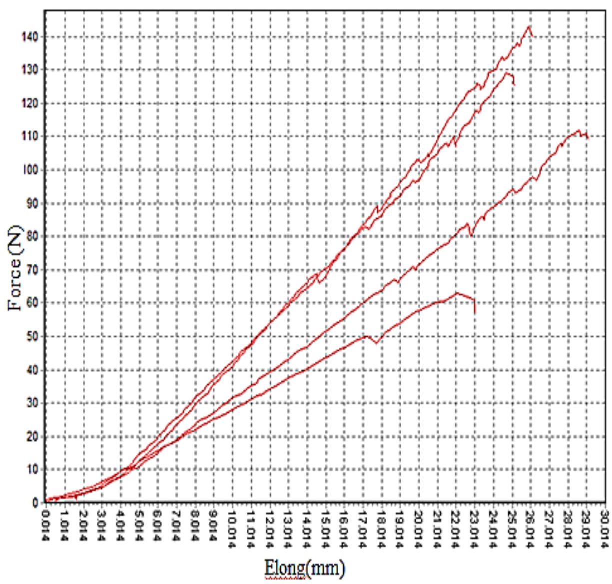

Figure 4.- Changes in hydrothermal destruction of laser modified sheep Wet-Blue leather semi-finished *samples after scraping process.*

Based on the obtained data, it was determined that the hydrothermal destruction of the laser-modified sheep Wet-Blue leather semi-product is 5.2% higher than the Wet-Blue leather semi-product produced based on standard technology.

Naturally, one of the main indicators for evaluating the quality of Wet-Blue leather semi-products is its strength and elongation at break. Because the leathers produced are required to be strong and elastic. For this reason, the elongation at break of the control and experimental sample of the increased Wet-Blue leather semi-product, as well as the strength limits, were determined using a cutting machine with the standard samples cut, and the results are shown in Figure 5.




A




B

Figure 5. Wet-Blue leather semi-finished product samples: A-Control sample, B-Experimental sample

Thus, it was found that Wet-Blue leather semi-finished products have improved physical and mechanical properties when the leather raw material is treated with laser light before the tanning process. It was found that the tensile strength of the average samples increased by 15,0-20,0 %, and the elongation at 10 MPa increased by 20,0-25,0 % compared to the Wet-Blue leather semi-product produced by traditional technology.

## IV. CONCLUSION

Thus, the possibilities of processing sheepskin leather with laser light were studied. The physical and mechanical properties of the Wet-Blue leather semi-product were determined and the results were presented and discussed. From the results, it was found that during the laser irradiation of unmodified skin raw materials, the destruction temperature of the collagen, which has a weak supramolecular structure and intermolecular chemical bonds, changes by 4.3% compared to the unmodified skin raw materials, and the hydrothermal destruction of these samples after the tanning process is 5,2 % higher. It was found that the tensile strength of laser-modified Wet-Blue leather semi-products increased by 15.0-20.0% in average samples, and the elongation at 10 MPa increased by 20,0-25,0 % compared to Wet-Blue leather semi-products produced by traditional technology.

By comparing the results of the physical and mechanical tests, it was noted that the laser-modified Wet-Blue leather semi-product has higher hydrothermal stability, strength, and elongation at break indicators compared to the control samples. It can be concluded from the results that as a result of laser irradiation, positive morphological changes occurred in the skin structure.

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