VII International scientific conference
„Contemporary trends and innovations in the textile industry"
19-20th September, 2024, Belgrade, Serbia

COMPARISON OF PHYSICAL AND MECHANICAL PROPERTIES OF CHROME AND VEGETABLE TANNED LEATHER

Original scientific paper
DOI: 10.5937/CT_ITI24030L

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ABSTRACT: *Leather making is a very long process and consists of many different chemical and mechanical operations. The most important operation of the whole leather making process is the tanning, which is performed mainly by vegetable or chrome tanning. With this work, we wanted to establish a connection between the way leather is tanned and its physical and mechanical properties. For this purpose, certain physical and mechanical properties of bovine, sheep and goat leather, which were obtained by chrome and vegetable tanning, were examined. Tests were performed on commercially available leathers. The selected leather samples were tested for thickness, mass per unit area, apparent density, braking force and breaking elongation, while other dimensions were calculated based on previously measured values. After the measurements, the results were compared according to the type of leather and the method of tanning. The obtained results showed better physical and mechanical properties of chrome-tanned leather compared to vegetable-tanned leather, with the highest breaking strength of chrome-tanned bovine leather (70.7 N/mm²). However, for a more precise analysis, when examining the physical and mechanical properties, it is necessary to have more precise data of the origin, tanning parameters and applied leather finishing. The chrome tanning process has advantages in terms of the shorter duration of the tanning process, but chrome tanning process has significant limitations in terms of environmental requirements, which is why the vegetable tanning process is becoming more relevant again.*

Keywords: *leather, chrome-tanned, vegetable-tanned, breaking strength.*

POREĐENJE FIZIČKO MEHANIČKIH SVOJSTAVA HROMNO I BILJNO ŠTAVLJENE KOŽE

APSTRAKT: *Process prerade kože je veoma dug i sastoji se od mnogo različitih hemijskih i mehaničkih operacija. Najvažnija operacija u procesu prerade kože je štavljenje, koje se najčešće izvodi biljnim ili hromnim štavilima. Ovim radom želeli smo da uspostavimo vezu između načina štavljenja kože i njenih fizičko-mehaničkih svojstava. U tu svrhu ispitvana su određena fizičko-mehanička svojstva goveđe, ovčije i kozije kože, koje su dobijene hromnim ili biljnim štavljenjem. Ispitivanja su izvođena na komercijalno dostupnim kožama. Na odabranim uzorcima kože ispitivani su: debljina, površinska masa, prividnu gustina, prekidna sila i prekidno izduženje, dok su druge veličine izračunate na osnovu prethodno izmjerenih vrijednosti. Nakon mjerenja, rezultati su upoređeni prema vrsti kože i metodi štavljenja. Dobijeni rezultati su pokazali bolja fizičko-mehanička svojstva hromno štavljenih koža u poređenju sa biljno štavljenim, sa najvećom prekidnom jačinom hromno štavljene goveđe kože (70.7 N/mm^2). Međutim, za precizniju analizu, pri ispitivanju fizičko-mehaničkih svojstava, neophodno je imati detaljnije podatke o porijeklu, parametrima štavljenja i primenjenoj završnoj obradi kože. Proces štavljenja hromom ima prednosti u pogledu kraćeg trajanja procesa štavljenja, ali i ograničenja u pogledu ekoloških zahtjeva, zbog čega biljno štavljenje ponovo dobija na značaju.*

Ključne reči: *koža, hromom štavljena, biljno štavljena, čvrstoća na kidanje.*

1. INTRODUCTION

The most significant process in leather making is the tanning operation. This process involves introducing tanning agents (tannins) into the leather structure and binding them with the functional groups of the leather's collagen, creating cross-links. Depending on the charge, the tannin will bind to the positive amino or negative carboxyl groups of the collagen [1].

Collagen has a spatial structure with a certain number of cross-links (hydrogen bonds). During reactions between the active groups of collagen and the active groups of the tannins, stronger and more durable bonds are formed. The strength of these bonds depends on the type of tanning agent and the method of tanning. By creating stronger and more durable bonds, the collagen's resistance to enzymes and hydrolyzing substances is increased, swelling is reduced, and resistance to tearing is enhanced [2,3].

Chrome and vegetable tannins are the most commonly used tanning agents. Research shows that up to 85% of the world's leather production is based on chrome tanning [4]. Studies also show that chrome-tanned leathers have good tensile properties, but they also have a negative impact on the environment and human health, which is why efforts are being made to reduce their use [4-6].

The main advantages of chrome tanning include the speed of tanning, the production of light, strong, and durable leathers that are easy to dye [3]. Vegetable-tanned leathers have lower thermal insulation, lower resistance to sweat, and contain more bound tanning agents, making them heavier and thicker compared to chrome-tanned leathers [2].
To compare the physical and mechanical properties of chrome and vegetable-tanned leathers, tests were performed on the following parameters: mass, mass per unit area, apparent density, breaking force, breaking elongation, and breaking strength. These tests aimed to identify differences in the structure of the finished leather resulting from the applied tanning process.

2. MATERIALS AND METHODS

2.1. Materials

Different leather samples were used as material for the experimental work, according to origin (bovine, sheep and goat leather) and according to the method of tanning leather (chrome tanning and vegetable tanning). All leathers were Full grain leathers. Table 1. gives an overview of the types of leather used and type of tanning.

Table 1: Type of leather samples and type of tanning

Sample	Type of leather	Type of tanning
Sample I	Bovine leather	Chrome tanning
Sample II	Bovine leather	Chrome tanning
Sample III	Bovine leather	Chrome tanning
Sample IV	Bovine leather	Chrome tanning
Sample V	Bovine leather	Vegetable tanning
Sample VI	Sheep leather	Vegetable tanning
Sample VII	Goat leather	Vegetable tanning

2.2. Methods

The test samples were prepared in accordance with the EN ISO 2418 [7] and conditioned in accordance with the EN ISO 2419 [8]. The following tests were performed on the prepared leather samples in order to determine the physical and mechanical properties:
- EN ISO 2589 [9] for the leather thickness measurement. Ten measurement were taken, disposed across the sample and obtained results expressed as the arithmetic mean of measurements. Used apparatus: thickness gauge J-200 (Scmidt Control Instruments, Germany) whit measuring range 1-10 mm and resolution of 0.01 mm.
- EN ISO 2420 [10] for the leather apparent density (D_a) and mass per unit area (m_a). Apparatus that are used: square steel press knife (dimension 100 mm x 100 mm), and previously mentioned thickness gauge. Calculation of the apparent density was performed by using equation 1. Calculation of mass per unit area was performed by using equation 2.

$$D_a = \frac{10^6 \cdot m}{t \cdot a \cdot b} \quad (1) \qquad\qquad m_a = \frac{10^6 \cdot m}{a \cdot b} \quad (2)$$

where:
t – the mean thickness of the test piece (mm); a – is the mean distance AC of the test piece in milimeters (mm); b – is the mean distance BD of the test piece in milimeters (mm); m – mass of the test peace in grams (g).

- EN ISO 3376 [11] for leather breaking force and breaking elongation. From the sample, ten test pieces were cut in standard dimensions to the leather surface - five test pieces with the side parallel to the backbone and five test pieces with the side perpendicular to the backbone. Breaking force (F), and breaking elongation (E_b), were measured using Tensile tester model AGS-10kNX (Schimadz, Japan) whit load capacity to 10 kN and test speed from 0.001 mm/min to 1000 mm/min. Breaking strength (T_n) in N/mm^2, was calculated using equation 3:

$$T_n = \frac{F}{w \cdot t} \quad (3)$$

where: F - the maximum force recorded (N); w - the mean width of the test piece (mm); t - the mean thickness of the test piece (mm).

3. RESULTS AND DISCUSSION

The mechanical and physical properties of the samples were systematically analyzed through various parameters such as breaking force, breaking elongation, mass per unit area, apparent density and breaking strenght.
Figure 1. shows the dependence of breking strength and mass per unit area for samples of chrome-tanned bovine leather, observed in the direction parallel and perpendicular to the backbone. Based on the results, we can conclude that the highest breaking strength in the direction parallel to the backbone is found in Sample II (70.7 N/mm^2), while the lowest breaking has Sample III (65.9 N/mm^2). The breaking strength of the tested samples in the direction parallel to the backbone, decreases with the reduction of mass per unit area. The breaking strength measurements in the direction perpendicular to the backbone are approximately the same for Sample II (40.8 N/mm^2) and Sample III (40.4 N/mm^2), while the highest breaking strength has Sample I (46.2 N/mm^2). The breaking strength of the tested samples in the direction perpendicular to the backbone doesn't follow changes in mass per unit area as it does in the direction parallel to the backbone.
The higher breaking strength observed for samples parallel to the backbone could be linked to specific factors such as denser collagen fiber networks or more effective cross-linking during the tanning process [2].

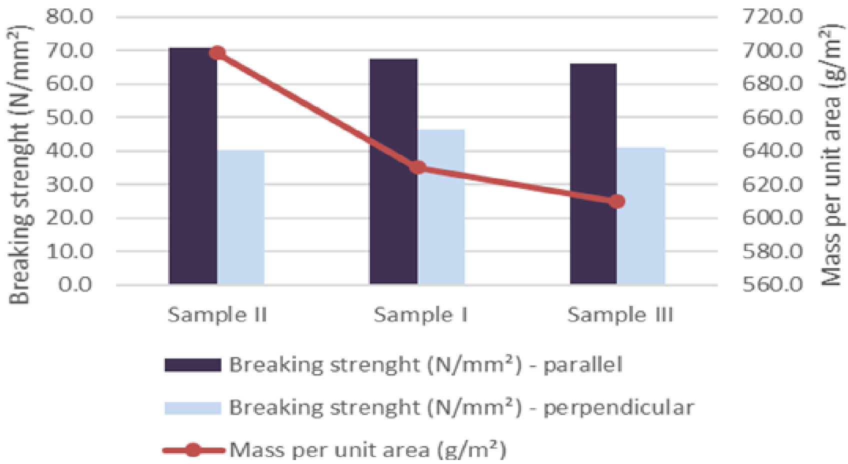

Figure 1: Dependence of breaking strenght on mass per unit area – Chrome-tanned leathers

Dependence of breaking elongation and apparent density for samples of chrome-tanned bovine leather is shown in Figure 2, observed in the direction parallel and perpendicular to the backbone. It is noticeable that the highest breaking elongation in the direction perpendicular to the backbone has Sample III (49.0 %), while the lowest breaking elongation has Sample II (37.5 %). The breking elongation in the direction parallel to the backbone are lower compared to the direction perpendicular to the backbone. Moreover, the breaking elongation for samples parallel to the backbone shows greater uniformity and are not significantly different from one to another. This consistency suggests a more uniform mechanical behavior along the backbone's parallel axis. The greatest breaking elongation in the direction parallel to the backbone has Sample III (32.9 %), while the smallest breaking elongation has Sample II (31.1 %). The cross-links between collagen fibers in the direction perpendicular to the backbone are significantly weaker and have a lower density compared to the direction parallel to the backbone, resulting in their greater breaking elongation [12]. Observing the dependence between breaking elongation and apparent density of chrome-tanned bovine leather, we notice that the breaking elongation of the tested samples in both directions increases with the decrease in apparent density.

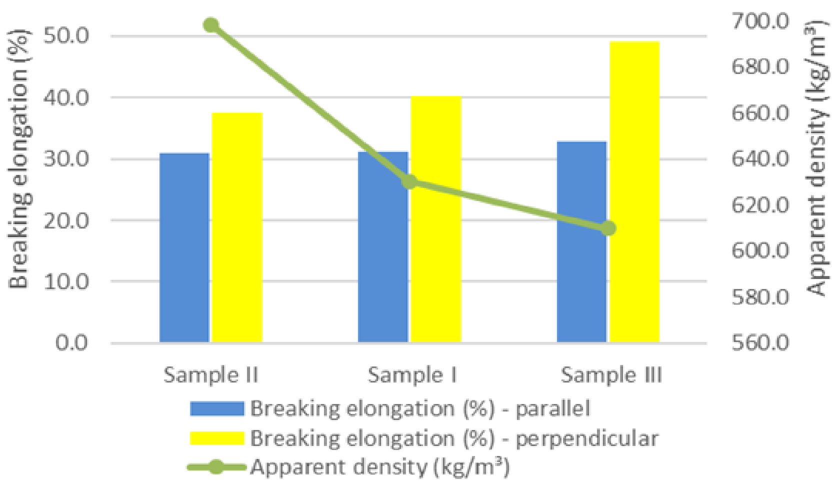

Figure 2: Dependence of breaking elongation on apparent density – Chrome-tanned leathers

Figure 3. shows the dependence between breaking strength and mass per unit area for samples of vegetable-tanned bovine, goat and sheep leathers, analyzed in the parallel and perpendicular directions relative to the backbone. The data indicate that Sample IV has the highest breaking strength in the direction parallel to the backbone (45.3 N/mm^2), while Sample VII shows the lowest breaking strength (19.2 N/mm^2). In the direction perpendicular to the backbone, Sample IV also shows the highest breaking strength (24.5 N/mm^2), with Sample VII again displaying the lowest (19.1 N/mm^2). A clear trend is observed where the breaking strength of the tested samples decreases in both directions as the mass per unit area is reduced. Notably, bovine leathers exhibit significantly higher breaking strength compared to goat and sheep leathers. This can be attributed to the greater weight, thickness, and density of bovine leathers, which confer superior mechanical properties. Conversely, goat and sheep leathers, derived from related animal species, are characterized by their lighter weight, flexibility and softness [1].

In the analysis of sample VII, we observed that the breaking strength values in both the parallel and perpendicular directions to the backbone are approximately equal. This uniformity in breaking strength is indicative of a balanced and homogeneous fiber structure, which is a sign of high-quality leather [12].

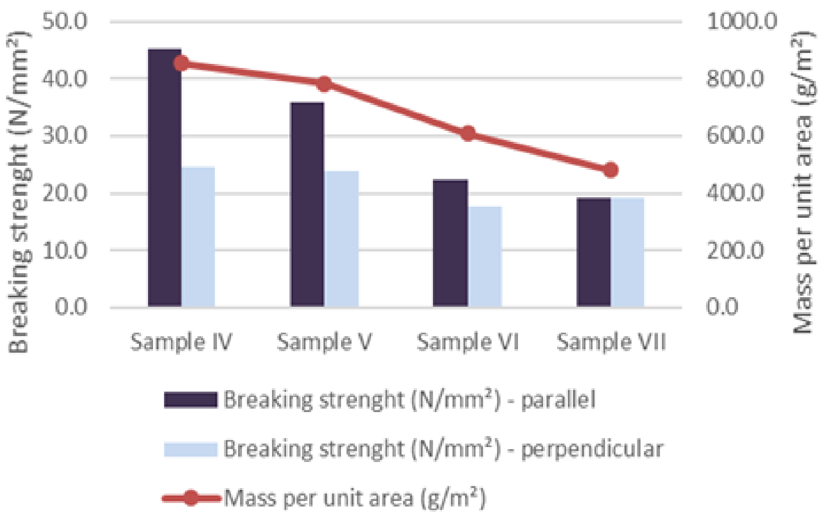

Figure 3: Dependence of breaking strenght on mass per unit area –Vegetable-tanned leathers

Figure 4. shows the dependence between breaking elongation and apparent density for samples of vegetable-tanned bovine, goat and sheep leather in directions parallel and perpendicular to the backbone. Based on the results, we can conclude that the highest breaking elongation in the direction perpendicular to the backbone has Sample VII (34.1 %), while the lowest breaking elongation has Sample IV (28.9 %). The highest breaking elongation in the direction parallel to the backbone has also Sample VII (27.9 %), while the lowest breaking elongation has Sample IV (23.3 %). In general, the breaking elongation of all tested samples in both directions (parallel and perpendicular to the backbone) increases with a decrease in apparent density. The highest breaking elongation in perpendicular and parallel direction has Sample VII (goat leather), which is 34.1 % and 27.9 %, respectively. The superior performance of Sample VII (goat leather) in both directions could be attributed to its unique structural properties. Goat leather is known for its tight and fine grain, which can enhance both strength and flexibility. The lower density of goat leather compared to bovine and sheep leather might contribute to its higher elongation [12].

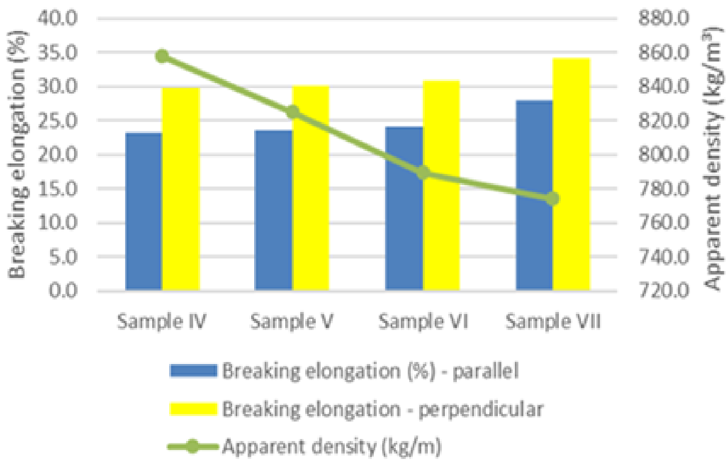

Figure 4: Dependence of breaking elongation on apparent density – Vegetable-tanned leathers

In order to compare the physical and mechanical properties of vegetable-tanned and chrome-tanned leathers of the same origin, samples of vegetable-tanned and chrome-tanned bovine leathers are observed in Figures 5. and 6. Based on Figures 5. and 6., we can see that the results for breaking strength and breaking elongation for the samples of chrome-tanned leathers are significantly higher compared to the samples of vegetable-tanned bovine leathers.

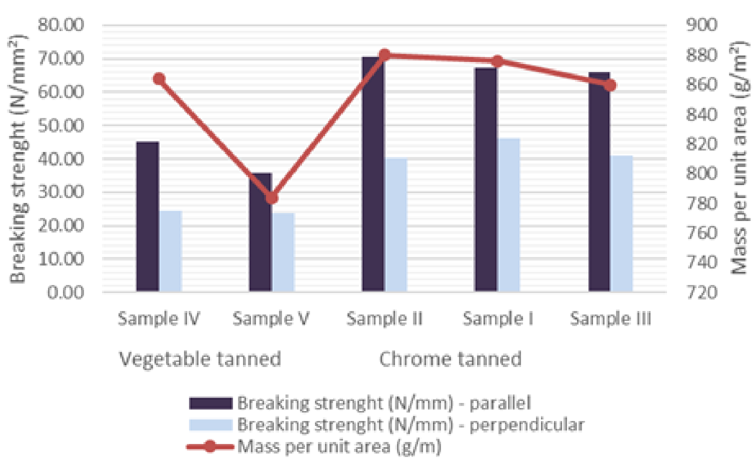

Figure 5: Comparison of breaking strenght on mass per unit area – Vegetable-tanned and chrome-tanned bovine leathers

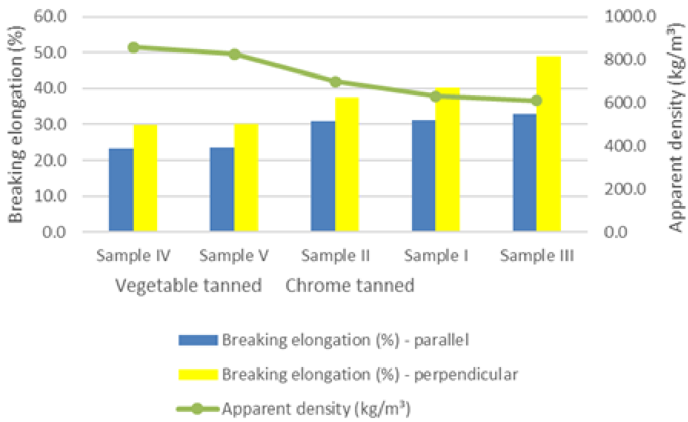

Figure 6. Comparison of breaking elongation on apparent density – Vegetable-tanned and chrome-tanned bovine leathers

4. CONSLUSION

The obtained results provide insight into the structural integrity and usability of the leather samples in potential applications. Physical and mechanical properties of leather are not influenced only by the tanning method but also by the origin of the animal. Certain deviations from expected results can be attributed to the lack of precise information regarding the finishing process, as well as the gender, age of the animal, ect. These factors, in conjunction with the tanning method and the animal's origin, are crucial in determining the physical and mechanical properties of the leather. Although, chrome-tanned leather has superior physical and mechanical properties, its environmental impact is a significant concern. Consequently, vegetable-tanned leather is recommended for applications where extreme physical and mechanical properties are not critical, thereby balancing performance with ecological considerations.

ACKNOWLEDGMENTS
This work was supported by European Union, Erasmus+ project: FOOTWEAR FAST FORWARD COOPERATION – Innovative agile training program and training opportunities for the digital and green twin transition in Bosnia (3F-COOP, Project No. 101129078).

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