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# MECHANICAL PROPERTIES OF TRADITIONAL DAIRY TANNED COW LEATHER STRIPS

# МЕХАНИЧЕСКИЕ СВОЙСТВА ПОЛОС КОРОВЬЕЙ КОЖИ ТРАДИЦИОННОГО МОЛОЧНОГО ДУБЛЕНИЯ

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***Study of naturally sustainable materials has been attractingconsiderable attention of researchers in recent years. In this respect, following study determines mechanical properties of Mongolian pasture-fed cow (mature cattle) leather strips that are organically tanned in traditional dairy solution using tensile test methodology.In this study, cowhide was divided into two symmetrical parts along the back bone.One half was processed using Mongolian traditional method, and the other was processed using the factory method.The density and Young's modulus of industrially and conventionally processed leather stripswere then determined experimentally in lab environment. The porosity of directly dried cowhide strips, conventionally and industrially processed leather strips were analyzed using ScanningElectron Microscopy (SEM). Based on the determined density, Young's modulus and mechanical properties were compared with the actual tensileexperimental results of simulation using finite element methodology.***

***Изучение природных устойчивых материалов привлекло значительное внимание исследователей в последние годы. В связи с этим целью данного исследования явилось определение механических свойств полос кожи монгольских коров, выкормленных на пастбищах (взрослый крупный рогатый скот), которые органически дубятся в традиционном молочном растворе. В этом исследовании коровья кожа была разделена на две симметричные части вдоль позвоночника. Одна половина была обработана с использованием монгольского традиционного метода, а другая – с использованием заводского метода. Затем были определены плотность и модуль Юнга промышленно и традиционно обработанных полос кожи. Пористость напрямую высушенных, традиционно и промышленно обработанных полос коровьей кожипроанализирована с помощью сканирующей электронной микроскопии (СЭМ). На основе определенной плотности модуль Юнга и механические свойства сравнены с фактическими результатами экспериментального моделирования растяжения с использованием методологии конечных элементов.***

**Keywords: cow leather, density, Young's modulus, leather porosity.**

**Ключевые слова: коровья кожа, плотность, модуль Юнга, пористость кожи.**

*Introduction*

Research and development of eco-friendly, animal derived raw materialshave become important in the recent years owing to concerns of global warming and greenhouse gas emissions. Leather is a natural, renewable material that decomposes in harmony with nature. It has been widely used by humanity for centuries as research and production technology for leather continue to evolve.

Research activities related to leather design, fabrication, processing started ab initio in 20th century. Accordingly, nowadays researchers mainly focus on the chemical processing of leather.

In our country, thecattle breeders, who have preserved their nomadic culture for more than 4000 years, use leather prepared by both traditional and industrial methods in their daily life [1]. Mongolian traditionally processed leather had the advantage of being lightweight, less elastic when wet, soft when dry, less shrinkable and not damaging to the skin of the animal on which it was used as cargo straps by nomads for long-distance travel or in their daily activities.

The production of Mongolian traditional leather continues throughout the year, and the mechanical properties of this leather are subject to many natural tests, conditions (age, gender, regional characteristics, processing methods, overall fatness of the cattle that year, etc.), as well as environmental influences (winter and summer weather, drought and severe winter, temperature) [1]. The durability and performance of leather also largely depend on tanning technology, smoking and greasing methods. Research has rarely been conducted to determine the mechanical properties of leather tanned by traditional methods of nomadic peoples or other cultures around the world, and there are no studies on the properties of leather traditionally produced from pastured cowhide adapted to the extreme climate and weather of Mongolia. Recently, some scientists have conducted research in the above area, for example, the density and Young's modulus of pastured, vegetable-tanned cowhide cut across the spine have been determined [2, 3].

Notably, number of young cattle breeders in our country are decreasing every year, due to labor shortage, and accordingly, traditional leather production continues to decline [1]. Therefore, it is imperative to design and introduce production devices that are ergonomic, economical, reliable, portable as well asenergy efficient, with engineering solutions based on learnings from traditional methods.

In this research work, mechanical properties and microstructural porosity of traditionally processed mature cowleather strips, which were cut longitudinally along the backbone and cured in traditional dairy in tannery, were determined. Also, the tensile simulation was carried out using finite element method and compared with the actual test results for further analysis and assessment.

Significantly, in-depth study of mechanical properties of material will allow to determine mechanical resistance caused by load applied to leather, thereby creating a new information data sets for traditionally processed materials which could be leveraged for simulations using engineering programs, as well as making it possible to invent new designs of processing equipment.

*Material and Methodology of Experiment*

Nomadic herders usually cut cowhide longitudinally along the back bone. In this study, we divided the cowhide into two equal parts lengthwise along the back bone, cut one side 4-6 cm wide strips and used the Mongolian traditional curing method, and the other half of the hide was tanned and prepared in leather factory for the experiment (fig. 1: 1 – traditionally prepared leather strip samples; 2 – factory prepared samples).

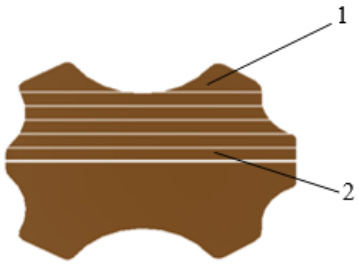



Fig. 1

We used the most commonly used traditional method of cutting and preparing

the strips. The traditional method has an independent technological sequence, which is shown in fig. 2 (conventional process steps of leather strip making) [5].


Fig. 2

Sequence of traditional leather processing technology:

- Cowhide is cut lengthwise along the back bone with a width of 2-3 fingers (4-6 cm).
- Freeze the cowhide strips and shave the hair with a sharp knife.
- Keep the cowhide strips in water with +1 to +4 degrees celsius until the soil turns white and the red juice disappears.
- Fold the strips into a circle and dry it gently in the wind through the winter and spring seasons in a shady dry place, away from the sunlight and from other domestic animals.
- Treat with 70% whey, 20% milk curd, 5% yogurt, 5% salt, bitter salt and saline mixture.
- Lubricate the leather strips with animal derived fat/oil and twist it using grinder.
- Smoke it for 1-2 days to make it last longer.

One half of the cowhide was prepared as leather strips in leather factory. Industrial leather strip making technology steps was shown in fig. 3 [6].

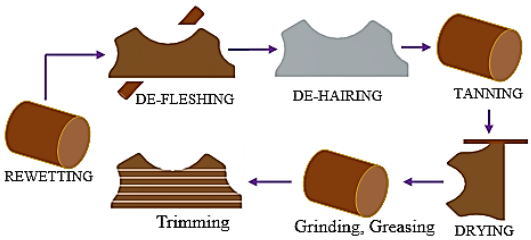



Fig. 3

Industrial leather strip making technology steps:

- Put cowhide in the drum to soak and spinat 2-4 rpm speed to both clockwise and counter clockwise for 15 minutes.
- Remove the fat adhering to the skin with a sickle knife and a dedicated machine.
- Apply hydrated lime with 100-110 g/l of sodium sulfate to the hair at a temperature of 35-40$^0$C to loosen it then remove the hair.
- Tanning for 48-60 hours in a lime solution with a temperature of 20-22$^0$C, stirring once every 4 hours. After tanning, wash off the lime.
- Stick the meat side up on the stick and let it dry for 18-24 hours.
- Lubricate with animal derived grease in hot air in a special drum at a temperature of 38-40$^0$C. Put it through grinding equipment 2 times until it softens and moisture is removed.
- Cut into 3-3.5 cm wide strips with a cutting machine.

Samples of 100x15x3 mm volume from each industrially and conventionally tanned strips were prepared. The prepared samples were weighed using electric weight scale.

The density of the material is one of the main indicators of its mechanical properties and is determined by the ratio of its mass to its volume:

$$\rho = m/V \text{ (g/cm}^3\text{)}, \quad (1)$$

$\rho$ – leather strip density; $m$ – leather strip mass; $V$ – volume.

Samples for microstructure analysis were prepared by taking 10x10 mm$^2$ squares from each of directly dried hides, industrially and traditionally prepared hides (Fig. 4: a – directly dried cowhide; b – industrially tanned; c – traditionally tanned).


Fig. 4

*Results and Discussion*

The microstructure was analyzed with a resolution of 500 μm using a TM-1000 with

SwiftED-TM brand SEM apparatus made in Japan in a cross-section along the backbone of the prepared sample (fig. 5: a – microstructure of directly dried hide, b – тmictrostructure of industrially tanned leather strip, c – micro-structure of traditionally tanned leather stripsa, b, c).

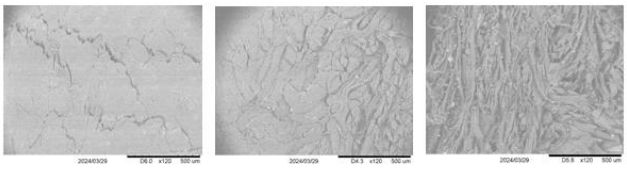


Fig. 5

Scientists Zheng li, Denis Paudecerf, and Jiashi Yang analyzed the microstructure of vegetable-tanned pasture-fed cow leather strips before and after the tensile test to determine the formation of bilayers along the leather strip thickness. In our study, we com-pared andanalyzed the porosity of directly dried hide strips, industrially processed leather strips, and conventionally processed leather strips.

In accordance with the requirements of the international standard ISO 3376 [7], the ten-siletest machine, dumbbell samples were prepared from industrially and traditionally tannedleather strips with the standard tensile dimensions.

The tensile test was performed using UH-1000kNX device from Shimadzu, Japan. During the test, samples were stretched (at a speed of 1 mm/min, at an ambient temperature of 22 $^0$C) to break. Young's modulus was determined using the results of the tensile test [4]:

$$E = \frac{FL_0}{A\Delta L} \text{ (N/mm}^2\text{)} , \qquad (2)$$

$E$ – Young's modulus; $F$ – applied force; $A$ – initial cross-section area; $\Delta L$ – the difference between the initial length and length at break, $L_0$ – initial length.

We determined thetensile strenght using Hooke's law:

$$\sigma = \varepsilon_{long} E . \qquad (3)$$

Nine samples each were taken from industrial and conventionally prepared leather strips and weighed with gram accuracy and mathematical average and variation coeffi-cient were determined (fig. 6).

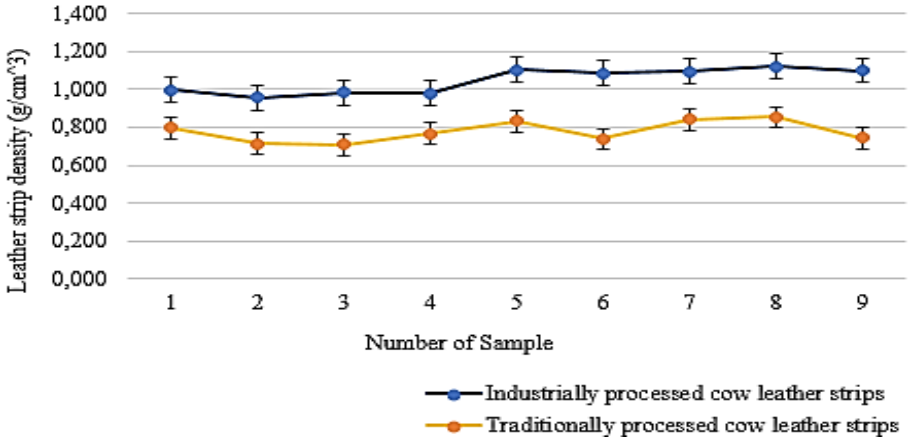



Fig. 6

Ten samples were taken from industrially and traditionally tanned leather strips for ten-sile test, the Young's modulus and mathematical average and variation coefficient were determined and the results are shown in fig. 7.

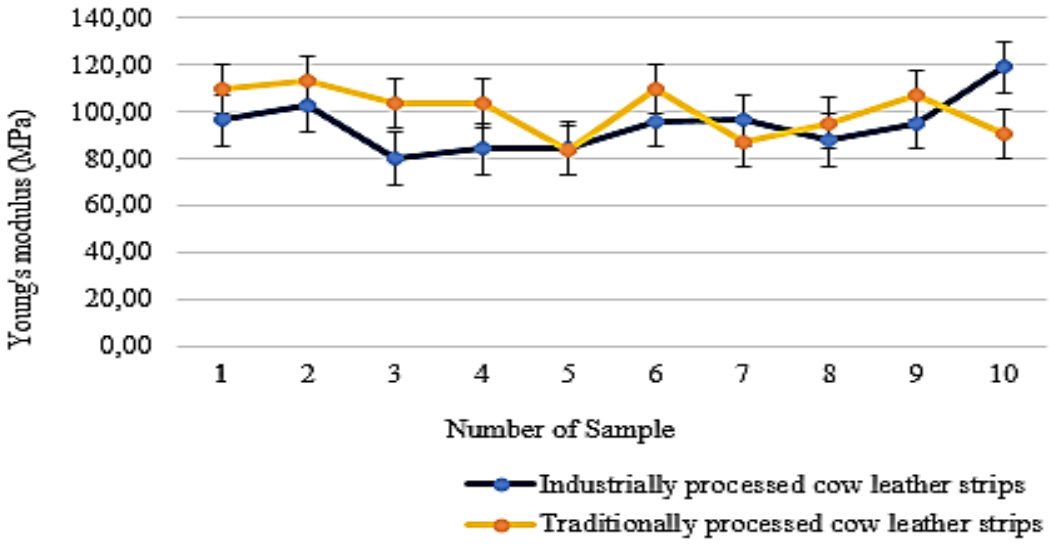



Fig. 7

Density, Young's modulus, cross-section area, tensile force, tensile strength, and deformation are determined in the 95% confidence interval of static parameters and shown in table 1 [8, 9, 10].

Table 1

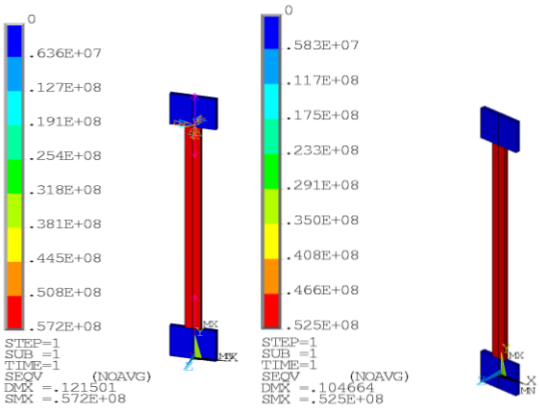
| Material property | Density ρ (kg/m^3) | Young's modulus E (MPa) | Cross-section area A (m^2) | Force F (N) | Tensile strength σ (MPa) | Deformation ε (m/m) |
|---|---|---|---|---|---|---|
| Industrially processed cow leather strips | 1.05±0.051 | 94.15±7.98 | 0.000031±5e-8 | 1773.11±39.94 | 56.8±2.72 | 0.61±0.063 |
| Traditionally processed cow leather strips | 0.78±0.043 | 100.25±7.52 | 0.000033±5e-8 | 1731.18±48.89 | 52.2±1.28 | 0.53±0.038 |

Using the experimentally determined parameters of the mechanical properties of industrially and traditionally tanned leather strips (table 2), the finite element method of elongation simulation was performed [11, 12, 13, 14].

Fig. 8 (a – tensile strength of industrially tanned leather strips, в – tensile strength of traditionally tanned leather strips) and fig. 9 (a – absolute elongation of industrially tanned leather strips, в – absolute elongation of traditionally tanned leather strips) show the simulation results of determining the tensile strength and absolute elongation of industrial and traditional leather strips.

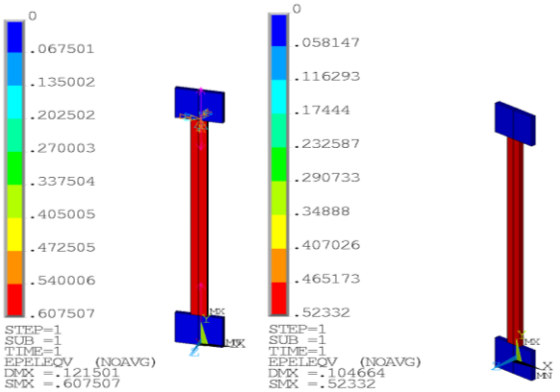
Table 2

| Material property | Industrially processed cow leather strips | Traditionally processed cow leather strips |
|---|---|---|
| Young's modulus E (MPa) | 94.15 | 100.24 |
| Poisson's ratio | 0.4 | |
| Density ρ (kg/m$^3$) | 1050 | 780 |
| Cross-section area A (m$^2$) | 0.000031 | 0.000033 |
| Force F (N) | 1773.1 | 1731.2 |




a) b)

Fig. 8




a) b)

Fig. 9

According to the above results, tensile strength of the industrially tanned leather is $\sigma_M = 57.2$ MPa, absolute elongation is $\varepsilon_M = 0.608$ m/m; tensile strength of the traditional dairy tanned leather is $\sigma_T = 52.5$ MPa, absolute elongation is $\varepsilon_M = 0.532$ m/m.

## CONCLUSION

The density of industrially processed leather strips is 1.05±0.051 kg/m^3, and the density of traditionally processed leather strips is 0.78±0.043 kg/m^3. The density of traditionally prepared leather strips is 25.71% lighter than the density of industrial leather strips.

The results of microstructure analysis done by the SwiftED-TM device with a resolution of 500um, the porosity of the traditionally tanned leather is higher than that of the directly dried hide and industrially tanned leather.

In the tensile test, Young's modulus of industrially tanned leatherstrips is 94.15±7.98 MPa, and the Young's modulus of dairy tanned leather strips is 102.25±7.52 MPa, thus the Young's modulus of dairy tanned leather is 7.92% higher.

Comparison of results of the simulation and the actual experiment shows that there is a difference of 0.69% for the tensile strength of industrially tanned leather strips and 0.57% for the dairy tanned leather strips. Also, there is a difference of 0.49% for the absolute elongation of industrially tanned leather and 1.32% for the absolute elongation of dairy tanned leather.

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