ISSN 2181-8622

Manufacturing technology problems

Scientific and Technical Journal Namangan Institute of Engineering and Technology

INDEX COPERNICUS INTERNATIONAL

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SLIB.UZ Scientific library of Uzbekistan

Volume 9
Issue 2
2024

MATHEMATICAL MODELING OF THE DEVELOPMENT TECHNOLOGY OF SELECTED LEATHER FOR THE TRANSFORMATION ASSORTMENT

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Abstract: In this article, calf, cow, sheep, and goat skins were processed for experimental options for the assortment of transformation bags, their physical-mechanical and chemical composition was determined, and a mathematical model was developed based on them. Based on the physico-mechanical and chemical composition, a mathematical model was developed and the values of the coefficients determined on the basis of the mathematical models were discussed. The values of the coefficients determined among the mathematical models of leather selected for the transformation assortment were discussed and the most useful one was selected. The chemical composition, physico-mechanical properties of calf, cow, sheep and goat skins obtained for experimental options were determined and a mathematical model was created and analyzed, its mathematical model was developed and useful leather for bags was determined.

Keywords: Transformational, changing, assortment, invention, useful model, convenient, functional, harmonious, modern, needs.

Introduction. Animal skin and its products are widely used in various industries. Shoes, bags, trinkets and other haberdashery made of leather products occupy an important place due to their beauty, biological activity, high quality and wide range of use. Assortments made of animal skin products are usually characterized by good heat retention, moisture impermeability, resistance to various flames, and high elasticity[1,2,3]. Today, in the production of shoes, bags and leather accessories, not only consumer demand or fashion direction, but also the choice of leather suitable for where and for what purpose the manufactured product will be used, for which season, and at the same time its special importance is attached to the creation of a model that corresponds to its characteristics, and many scientific researches are being carried out [4,5,6,7].

Depending on the type of leather raw material, the method of cooking, the character and composition of the finishing are different. All processes of processing calf, cow, sheep and goat skins for experimental options for the assortment of transformation bags were carried out according to the method of "ANTIK ASL CHARM" and "YUKSALISH CHARM SANOAT" LLC enterprises, the chemical composition, physical and mechanical properties of the finished product were determined and a mathematical model of leather production technology was developed.

Methods. For experimental options, determine the chemical composition, physical and mechanical properties of calf, cow, sheep and goat leather obtained from "ANTIK ASL CHARM" and "YUKSALISH CHARM SANOAT" LLC enterprises based on existing standards and develop a mathematical model of leather production technology, to discuss the values of the coefficients determined on the basis of mathematical models and to determine the useful leather for the bag.

Results and discussions. Leather obtained from different types of animal skins must meet the requirements of State Standards. Therefore, the physico-mechanical properties of the finished leather obtained for experimental testing were conducted on the modern equipment installed in the testing laboratory of the Namangan Institute of Engineering Technology, based on the requirements of the DST 940-81 standard, and the physico-chemical and mechanical properties of the leather were determined. [15].

Table 1. Physico-chemical indicators of finished leather.

№	Indication	Cow leather	Goat leather	Calf leather	Goat leather	Standard, DST 940-81
1.	Moisture content, %:	15,9	14,5	13,5	12,9	10-16
2.	Ash content, %:	4,45	5,35	7,45	10,4	
3.	Chromium oxide content, not less than %	6,5	4,4	1,36	5,9	3,3 0,6-2,0
4.	The amount of substances extracted on the basis of organic solvents, not less than %	5,38	4,09	4,69	4,38	3,7
5	Ripening temperature, ºS	95	87	80	85	80-95
6	Tensile strength of 10 MPa, not less than %	3	2,5	1,3	2,0	1,3
7	Elongation at 5 MPa stress, %:	30	35,3	40,8	32,0	15-40

A mathematical model for the breaking strength of the product under the influence of cooking temperature and an analytical function for each case were created, and this mathematical model was explained based on the following table (table 3).

Table 2. Ripening temperature and tensile strength of experimental options.

t_i	95	87	80	85
u_i	3	2,5	1,3	2,0

Here t_i is the temperature, u_i is the breaking strength of the product.

$$S(a_1, a_2, \dots, a_k) = \sum_{i=1}^{4}[u_i - U_i]^2 = \sum_{i=1}^{4}[u_i - f(t_i, a_1, a_2, a_3, a_4)]^2 \rightarrow min \quad (1)$$

$$f(t_i, a_1, a_2, a_3, a_4) = a_1 + a_2 t_i + a_3 {t_i}^2 + a_4 {t_i}^3$$

For this process, initially, the system of equations (1) was derived from the system of differential equations (2):

$$\begin{cases} \sum_{i=1}^{4} 2[u_i - a_1 - a_2 t_i - a_3 {t_i}^2 - a_4 {t_i}^3] = 0 \\ \sum_{i=1}^{4} 2[u_i - a_1 - a_2 t_i - a_3 {t_i}^2 - {t_i}^3]\, t_i = 0 \\ \sum_{i=1}^{4} 2[u_i - a_1 - a_2 t_i - a_3 {t_i}^2 - a_4 {t_i}^3]\, {t_i}^2 = 0 \\ \sum_{i=1}^{4} 2[u_i - a_1 + a_2 t_i + a_3 {t_i}^2 + a_4 {t_i}^3]\, {t_i}^3 = 0 \end{cases} \quad (2)$$

The following system of equations (9) was derived from the system of equations (2).

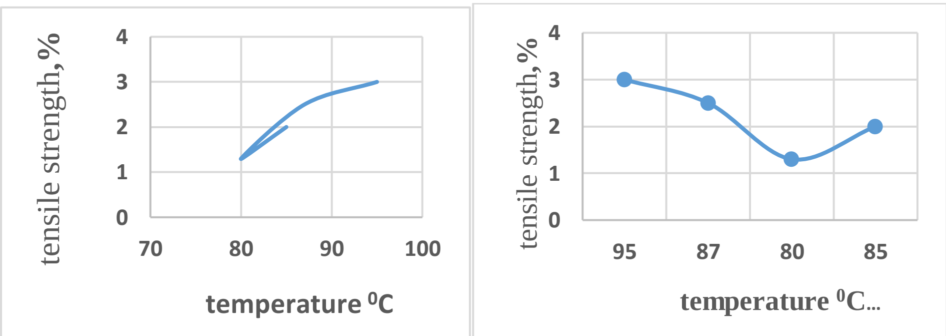
$$\begin{cases} 4a_1 + a_2 \sum_{i=1}^{4} t_i + a_3 \sum_{i=1}^{4} t_i^2 + a_4 \sum_{i=1}^{4} t_i^3 = \sum_{i=1}^{4} u_i \\ a_1 \sum_{i=1}^{4} t_i + a_2 \sum_{i=1}^{4} t_i^2 + a_3 \sum_{i=1}^{4} t_i^3 + a_4 \sum_{i=1}^{4} t_i^4 = \sum_{i=1}^{4} t_i u_i \\ a_1 \sum_{i=1}^{4} t_i^2 + a_2 \sum_{i=1}^{4} t_i^3 + a_3 \sum_{i=1}^{4} t_i^4 + a_4 \sum_{i=1}^{4} t_i^5 = \sum_{i=1}^{4} t_i^2 u_i \\ a_1 \sum_{i=1}^{4} t_i^3 + a_2 \sum_{i=1}^{4} t_i^4 + a_3 \sum_{i=1}^{4} t_i^5 + a_{k+1} \sum_{i=1}^{4} t_i^6 = \sum_{i=1}^{n} t_i^3 u_i \end{cases} \quad (3)$$

Unknown coefficients were determined by calculating the resulting system of equations (3) using the inverse matrix.

$$\begin{pmatrix} 36113652{,}46 & 2462822{,}31 & 169025{,}31 & 11675{,}37 \\ 2462822{,}31 & 169025{,}31 & 11675{,}37 & 811{,}72 \\ 169025{,}31 & 11675{,}37 & 811{,}72 & 56{,}80 \\ 11675{,}37 & 811{,}72 & 56{,}80 & 4 \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix} = \begin{pmatrix} 55036{,}41 \\ 3803{,}67 \\ 264{,}66 \\ 18{,}54 \end{pmatrix} \quad (4)$$

(4) by solving the system of equations $a_1 = 0{,}428583953$; $a_2 = -18{,}19291922$; $a_3 = 256{,}7087677$; $a_4 = -1199{,}709248$ by solving the system of equations f=-1199.71+256.71*x-18.19*x²+0.43*x³ function parameters are defined

Based on the above system matrices, the function and diagram of the effect of temperature t_i , u_i on the breaking strength of the product was created using the Excel program



a) b)

Figure 1. The effect of product tensile strength at cooking temperature based on chemical element.

In (a)-experiment (b)-mathematical modeling

The mathematical model for the rate of reaction of a chemical element in the process of growth is presented on the basis of the following table:

Table 3. The mathematical model for the rate of reaction of a chemical element in the process of growth.

t_i	95	87	80	85
ϑ_i	113.04	75.36	9.42	9.42
u_i	5.38	4.09	4.69	4.38

Here t_i- is the temperature, ϑ_i-is the average rate of the reaction, u_i- is the yield of substances extracted on the basis of organic solvents.

$$S(a_1, a_2, \dots, a_k) = \sum_{i=1}^{4}[u_i - U_i]^2 = \sum_{i=1}^{4}[u_i - f(t_i, \vartheta_i, a_1, a_2, a_3, a_4)]^2 \to min$$

$$f(t_i, \vartheta_i, a_1, a_2, a_3, a_4) = a_1 t_i + a_2 {t_i}^2 + a_3 t_i \vartheta_i + a_4 {\vartheta_i}^2$$

In this process, the system of equations (5) was derived from the system of differential equations (2) using the following system of homogeneous linear equations:

$$\begin{cases} \sum_{i=1}^{4} 2[u_i - (a_1 t_i + a_2 {t_i}^2 + a_3 t_i \vartheta_i + a_4 {\vartheta_i}^2)] t_i = 0 \\ \sum_{i=1}^{4} 2[u_i - (a_1 t_i + a_2 {t_i}^2 + a_3 t_i \vartheta_i + a_4 {\vartheta_i}^2)]\, {t_i}^2 = 0 \\ \sum_{i=1}^{4} 2[u_i - (a_1 t_i + a_2 {t_i}^2 + a_3 t_i \vartheta_i + a_4 {\vartheta_i}^2)]\, t_i \vartheta_i = 0 \\ \sum_{i=1}^{4} 2[u_i - (a_1 t_i + a_2 {t_i}^2 + a_3 t_i \vartheta_i + a_4 {\vartheta_i}^2)]\, {\vartheta_i}^2 = 0 \end{cases} \quad (5)$$

This system of linear equations is represented as follows.

$$\begin{cases} a_1 \sum_{i=1}^{4} t_i^2 + a_2 \sum_{i=1}^{4} t_i^3 + a_3 \sum_{i=1}^{4} t_i^2 \vartheta_i + a_4 \sum_{i=1}^{4} t_i {\vartheta_i}^2 = \sum_{i=1}^{4} u_i t_i \\ a_1 \sum_{i=1}^{4} t_i^3 + a_2 \sum_{i=1}^{4} t_i^4 + a_3 \sum_{i=1}^{4} t_i^3 \vartheta_i + a_4 \sum_{i=1}^{4} t_i^2 {\vartheta_i}^2 = \sum_{i=1}^{4} u_i t_i^2 \\ a_1 \sum_{i=1}^{4} t_i^2 \vartheta_i + a_2 \sum_{i=1}^{4} t_i^3 \vartheta_i + a_3 \sum_{i=1}^{4} t_i^2 {\vartheta_i}^2 + a_4 \sum_{i=1}^{4} t_i {\vartheta_i}^3 = \sum_{i=1}^{4} u_i t_i \vartheta_i \\ a_1 \sum_{i=1}^{4} t_i {\vartheta_i}^2 + a_2 \sum_{i=1}^{4} t_i^2 {\vartheta_i}^2 + a_3 \sum_{i=1}^{4} t_i {\vartheta_i}^3 + a_{k+1} \sum_{i=1}^{4} {\vartheta_i}^4 = \sum_{i=1}^{n} u_i {\vartheta_i}^2 \end{cases} \quad (6)$$

(7) solved the system of linear equations by the inverse matrix method and searched for the unknown parameters.

$$\begin{pmatrix} 30219 & 1614.43 & 141173.21 & 7595.42 \\ 1614.43 & 141173.21 & 7595.42 & 667220.53 \\ 141173.21 & 7595.42 & 667220.53 & 7595.42 \\ 7595.42 & 667220.53 & 36141.13 & 1969.48 \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix} \cdot = \begin{pmatrix} 1614.43 \\ 141173.21 \\ 7595.42 \\ 411.33 \end{pmatrix} \quad (7)$$

In the inverse matrix method (7), the system of linear equations is solved, the unknown coefficients are determined, the parameters are found to be equal to the following values.

$$a_1 = -3.611090762;\ a_3 = -0.000773448;\ a_3 = 0.773031873;\ a_4 = 0.211685255$$

Based on the defined parameters, the binding function was created

$$f(t_i, \vartheta_i, a_1, a_2, a_3, a_4) = -3.611090762 \cdot t_i - 0.000773448 \cdot t_i^2 + 0.773031873 \cdot t_i \cdot \vartheta_i + 0.211685255 \cdot \vartheta_i^2$$

The spatial graph of the effect of the reaction rate and temperature on the product of the leather raw material is shown in the following pictures (Fig. 2).

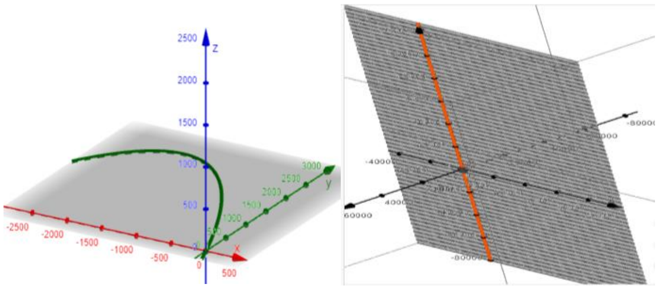


Figure 2. The graph of the rate of reaction of leather raw materials under the influence of temperature and the yield of the product.
(a) in experiment, (b) in mathematical modeling.

The mathematical model of the temperature and the average speed of the reaction to the product of the moisture content during the growth process was created on the basis of the following table.

Table 4. Effect of temperature and average rate of reaction on yield of moisture content.

t_i	95	87	80	85
ϑ_i	5,28	6,73	7,89	5,27
u_i	15,9	14,5	13,5	12,9

Here t_i- is the temperature, ϑ_i- is the average rate of the reaction, and u_i- is the product of the moisture content.

$$S(a_1, a_2, \dots, a_k) = \sum_{i=1}^{4}[u_i - U_i]^2 = \sum_{i=1}^{4}[u_i - f(t_i, \vartheta_i, a_1, a_2, a_3, a_4)]^2 \to min$$

$$f(t_i, \vartheta_i, a_1, a_2, a_3, a_4) = a_1 t_i + a_2 {t_i}^2 + a_3 t_i \vartheta_i + a_4 {\vartheta_i}^2$$

We derive the system from (2) to (8).

$$\begin{cases} \sum_{i=1}^{4} 2[u_i - (a_1 t_i + a_2 {t_i}^2 + a_3 t_i \vartheta_i + a_4 {\vartheta_i}^2)] t_i = 0 \\ \sum_{i=1}^{4} 2[u_i - (a_1 t_i + a_2 {t_i}^2 + a_3 t_i \vartheta_i + a_4 {\vartheta_i}^2)] {t_i}^2 = 0 \\ \sum_{i=1}^{4} 2[u_i - (a_1 t_i + a_2 {t_i}^2 + a_3 t_i \vartheta_i + a_4 {\vartheta_i}^2)] t_i \vartheta_i = 0 \\ \sum_{i=1}^{4} 2[u_i - (a_1 t_i + a_2 {t_i}^2 + a_3 t_i \vartheta_i + a_4 {\vartheta_i}^2)] {\vartheta_i}^2 = 0 \end{cases} \quad (8)$$

It was transferred to this system.

$$\begin{cases} a_1 \sum_{i=1}^{4} t_i^2 + a_2 \sum_{i=1}^{4} t_i^3 + a_3 \sum_{i=1}^{4} t_i^2 \vartheta_i + a_4 \sum_{i=1}^{4} t_i {\vartheta_i}^2 = \sum_{i=1}^{4} u_i t_i \\ a_1 \sum_{i=1}^{4} t_i^3 + a_2 \sum_{i=1}^{4} t_i^4 + a_3 \sum_{i=1}^{4} t_i^3 \vartheta_i + a_4 \sum_{i=1}^{4} t_i^2 {\vartheta_i}^2 = \sum_{i=1}^{4} u_i t_i^2 \\ a_1 \sum_{i=1}^{4} t_i^2 \vartheta_i + a_2 \sum_{i=1}^{4} t_i^3 \vartheta_i + a_3 \sum_{i=1}^{4} t_i^2 {\vartheta_i}^2 + a_4 \sum_{i=1}^{4} t_i {\vartheta_i}^3 = \sum_{i=1}^{4} u_i t_i \vartheta_i \\ a_1 \sum_{i=1}^{4} t_i {\vartheta_i}^2 + a_2 \sum_{i=1}^{4} t_i^2 {\vartheta_i}^2 + a_3 \sum_{i=1}^{4} t_i {\vartheta_i}^3 + a_{k+1} \sum_{i=1}^{4} {\vartheta_i}^4 = \sum_{i=1}^{n} u_i {\vartheta_i}^2 \end{cases} \quad (9)$$

(9) The system of equations is converted into matrix form as follows:

$$\begin{pmatrix} 30219 & 2642003 & 187163.12 & 13929.79 \\ 2642003 & 187163.12 & 13929.79 & 1193497.16 \\ 187163.12 & 13929.79 & 1193497.16 & 92237.65 \\ 13929.79 & 1193497.16 & 92237.65 & 7475.31 \end{pmatrix} * \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix} = \begin{pmatrix} 0.0224953 \\ 0.001435511 \\ -0.002019591 \\ 0.061313349 \end{pmatrix}$$

(10) The following parameters were determined by solving the system of equations $a_1 = 0.0224953$ $a_2 = 0.001435511$ $a_3 = -0.0012019591$ $a_4 = 0.061313349$;

we construct the dependence polynomial function of the determined parameters.

$$f = 0.0224953 \cdot t_i + 0.001435511 \cdot t^2 - 0.0012019591 \cdot t \cdot \vartheta + 0.061313349 \cdot \vartheta^4$$

Figure 4 shows the influence of temperature and the average rate of reaction of chemical elements on the yield of moisture with the help of built-in multifunction software.

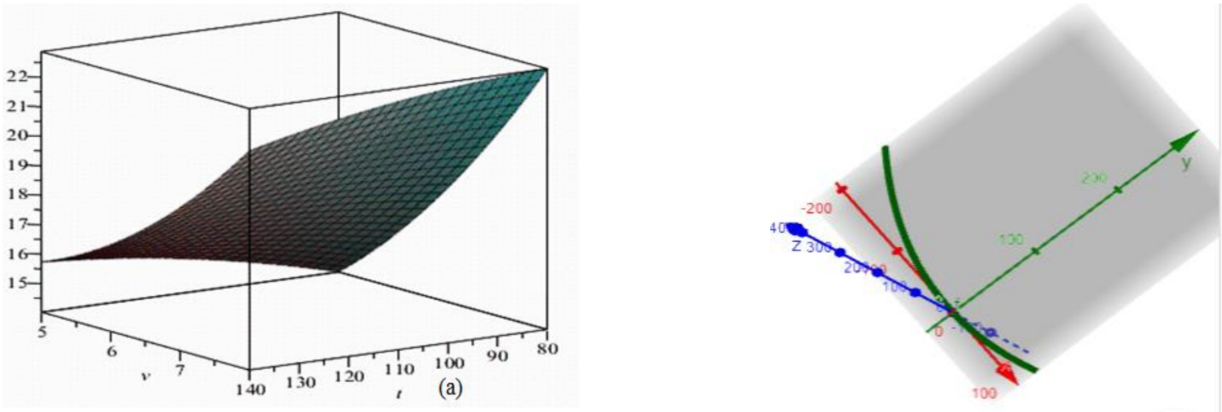


Figure 2. Graphs of the influence of temperature and the average rate of reaction of chemical elements on the yield of moisture content in (a)-experiment (b)-mathematical modeling.

The effect of temperature and the average speed of the reaction depends on the moisture content of the work process was also mathematically modeled.

Conclusion. From the above analysis, we concluded the following. The chemical composition, physico-mechanical properties of calf, cow, sheep and goat skins obtained for experimental options were determined, and a mathematical model was created and analyzed. It should be noted that leathers made from all animal skins differ according to the type of raw material, the method of cooking, the nature of finishing, and the composition. Also, the characteristics of different leathers for the transformation range were researched, its mathematical model was developed and the useful leather for the bag was determined. The experimental results obtained in the given graphs and tables show that a mathematical model for the breaking strength of the product under the influence of the ripening temperature and an analytical function for each case were created, and based on it, it was determined that the higher the temperature the leather is ripened, the stronger it is: the strength at a temperature of 95 oC is 3 % increased (Fig. 1).

It can be seen from the dependence graph of the average reaction rate and productivity of chemical elements in the production of leather products that the reaction rate of chemical elements was high (around 113) when the temperature was around 95 °C. It can be seen from Figure 3 that as a result of increasing the temperature and correspondingly increasing the average speed of the reaction of chemical elements, the moisture content decreased.

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CONTENTS

MECHANICS AND ENGINEERING