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# RHEOLOGY IN STANDARDIZED FOOD FORMATION PROCESSES

*The article examines the formation of food products, particularly meat-based ones, produced from structured raw materials. The quality of the forming process is of critical importance and depends on the physico-mechanical properties of the raw materials (viscosity, plasticity, adhesion) and the correct selection of technological parameters.*

*Standardization plays a key role in this process, ensuring consistency in the requirements for raw material composition, equipment parameters, and production conditions. National (DSTU) and international (ISO) standards define the norms for the rheological characteristics of food masses, forming accuracy, sanitary requirements, and permissible thermal and mechanical loads. Adherence to these standards enables consistent product quality, safety, and efficiency in the production process.*

*Further research into forming processes should be based not only on the physicochemical properties of the mass but also on the requirements of current standards regulating food production under industrial conditions.*

*The article presents the results of theoretical and experimental studies on the compression mechanism of concentrated, comminuted food raw materials, taking into account the standardization requirements for product forming processes. To model the behavior of food masses, the Kelvin body rheological model was selected, which accounts for the viscoelastic properties of the systems. This approach allows the behavior of products during deformation to be formalized in accordance with the standard technological parameters outlined in regulatory documentation for meat products.*

*The research results, demonstrating the relationship between deformation and the duration and conditions of loading, were presented graphically. For the first time, the mechanism of residual plastic deformation was scientifically substantiated, and a mathematical model was developed for its calculation, which enables its consideration in quality control systems in accordance with current standards.*

*These approaches can be integrated into standardized methods for monitoring and optimizing forming processes in the food industry.*

***Key words:*** *formation of food products, deformation of dispersed systems, rheology, mathematical modelling of deformation, residual deformation, standardization, quality control.*

**Introduction.** Molded meat, confectionery, dairy products and many other products obtained from pre-crushed raw materials occupy a significant share in the production of food products. In the technology of such products, raw materials with various cohesive and viscous-elastic-plastic properties are used, as well as special technological equipment with working bodies of various designs, the principle of work of which includes a compression mechanism. Depending on the technology of molded food products, crushed raw materials are loaded into the mold and compressed with a piston during linear or other devices during volumetric deformation. During volumetric forming, compression is carried out in special devices that ensure the all-round effect of the force load. Compression, both linear and volumetric, can be with a change in the volume or shape of the product and with or without mass loss.

The complexity of modeling the processes of formation of dispersed food systems is that their

**Fig. 1. Samples of molded products of the same weight and different volumes**

rheological properties change during deformation, which makes such systems not always obey the classical laws of rheology. This complicates the development of unified approaches to their processing and formation. Improving the mechanism of food formation and improving their quality remains a relevant scientific and technical task.

The solution of this problem is possible by conducting fundamental studies of mechanisms of deformation of concentrated dispersed systems with the simultaneous development and implementation of standardized methods of evaluating their rheological characteristics. This approach allows to ensure the unity of technological requirements, the reproducibility of the results and the conformity of products to the current standards (DSTU, ISO), which is especially important in the conditions of serial production and quality control.

**Purpose and methods of the research.** The purpose of the study is to model and optimize the process of formation of concentrated food dispersion systems to determine the optimal compression modes taking into account the rheological and adhesive properties of the common phase to present new results of theoretical studies of the relationship between the rheology of crushed food. The practical purpose of the study is to provide recommendations for determining the amount and rate of deformation required to optimize the formation of crushed raw materials with various structural and mechanical properties during its loading and unloading, obtaining high quality structured foodstuffs, in accordance with standards.

During the research, the methods of mathematical, physical and analog modeling of the structural and mechanical properties of food dispersion systems, theoretical developments of engineering rheology and rheodynamics were used. Mathematical modelling was performed using the methods of symbolic computer mathematics "Maple", the research results are presented in the form of the mathematical equations and 3D graphs.

**Presentation of the main material.** In the technology of molded food products, various raw materials with viscous - elastic - plastic properties are used together with special technological equipment with working bodies of various shapes, the principle of which includes a compression mechanism [1, 2, 11, 15, 16].

The conducted analytical studies had proved that the quality of the finished molded products directly depends on the adhesive properties of the raw materials, the modes of deformation and the structural features of the technological equipment.

The most common technological equipment is in which raw materials are loaded into a mold and compress with a piston during linear or other devices during volumetric deformation [8, 9]. During the volumetric forming, compression is carried out in special devices that ensure the all-round effect of the force load.

Compression is linear and volumetric, it can be both with a change in the volume or shape of the product, and with or without loss of the mass. An example of linear and volumetric deformation of crushed food viscoelastic dispersion systems is shown in Fig. 2.

A specific requirement for a semi-finished product is its ability not to fall apart but to keep its shape after removing the load and stopping the deformation process. In order to obtain the quality product, the ratio between the dispersed medium and the dispersed phase of the system and the high cohesive properties of the latter are important. The rheological properties of the product affect the process and modes of compression and, accordingly, the quality of the formation [6, 10].

**Fig. 2. Food molding equipment**

Therefore, the modelling of the formation processes of food dispersion systems is performed according to the laws of the applied rheology.

The rheology of food products in a broad sense is the science of deformation and flow of materials that have properties different from the properties of classical, or, as they are called, ideal bodies [4]. Combinations formed from them make it possible to consider the behaviour of real products under different deformation conditions, pressures and compression speeds, both constant and variable according to linear and non-linear laws.

Taking into account the variety of rheological properties of food products, the use of a variable force load during their deformation is relevant and promising for modelling the shaping of structured food products, and it is promising to use the basic regularities of the component part of rheology, rheodynamics. It is the basis for improving the theory of deformation and flow modelling of concentrated low-flow and non-flow dispersed systems under constant and variable power loads and unloaded conditions. The analysis of literary sources did not reveal qualitative mathematical models of deformation of structured food dispersion systems under variable force loading and its removal.

In the rheodynamic modelling of the forming process, the basis for the analysis and construction of rheological models are mechanical models in the form of springs, dampers, and dry friction bodies connected in a certain sequence.

In this case, the stiffness characteristic of the spring may not be taken as a constant value when it is loaded and unloaded, while the characteristic of the damper (viscosity), as a rule, remains constant in the specified interval of the deformation rate. The residual deformation after removal of the load is characterized by the displacement of the dry friction body (Sen-Venan body).

The process of deformation is described by the differential equations that connect the loads and deformations of the system, their first and higher order derivatives – speed and acceleration [5]. A common rheological model of concentrated food dispersion systems is the Kelvin body. Its mechanical model looks like this [1, 2, 3]:

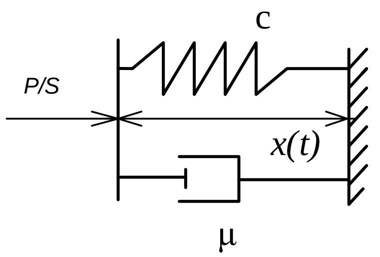


**Fig. 3. Mechanical model of the Kelvin body (viscoelastic rheological system)**

The equation that describes the mechanism of compression of food dispersion systems, when their rheological characteristics $\mu$ and $c$, the force $P$ and the compression surface $S$ are known, has the following form:

$$\begin{cases} \frac{P}{S} = \mu \frac{dx(t)}{dt} + cx(t) \\ x(t) = \frac{L_н - L_m(t)}{L_н} = 1 - \frac{L_m(t)}{L_н} \end{cases}, \quad (1)$$

where $x(t)$ is the relative deformation, dimensionless; $P$ – compression force, $N$; $S$ – compression surface, m$^2$; $L_н$ – the initial size of the sample, m; $L_m(t)$ – its current size, m; $t$ – compression duration, sec.; $\mu$ and $c$ – respectively, viscous and elastic rheological characteristics, Pa·s; Pa.

Solution of the equation (1) under initial conditions:

$$x(0) = 0$$

$$L(t) = L_н - \frac{L_н P}{c \cdot S} + e^{-\frac{ct}{\mu}} (L_н + \frac{L_н P}{c \cdot S}). \quad (2)$$

After differentiating of the equation (2), we obtain the rate of the deformation. By multiplying it to the compression force, we will find the energy consumption:

$$N = \frac{PL_н}{\mu \cdot S}(c \cdot S - P)e^{-ct_1}, \quad (3)$$

where $N$ is power, Watt.

The obtained mathematical models allow to carry out analytical studies of the formation mechanism, to optimize energy costs for the deformation of viscous-elastic food dispersion systems [7].

From the consumer needs, it is important to obtain the same mass of the finished products. You can adjust the mass of the finished product by knowing the relationship between the product density and the amount of deformation. The density of the product depending on the duration, compression force and its rheological properties will be:

$$\rho(t) = \frac{L_н \rho_н}{L(t)}. \quad (4)$$

If the density increased due to the release of the liquid fraction and air, then the mass would change as a result of the deformation. It can be determined from the equation:

$$m = Q \cdot \rho(t), \quad (5)$$

where $Q$ is the volume of the product.

The last equation has important practical significance for obtaining molded products of the same mass.

Under the technological conditions for the production of high-quality molded products, it is necessary to have $\rho(t) \le \rho_к$. Where $\rho_к$ is the critical density of the product, with the increase of which liquid begins to be released, or undesirable changes in its quality occur.

The mechanism of formation of concentrated crushed food dispersion systems has its own characteristics [12, 13, 14]. In order to obtain a high-quality molded food product, it is necessary to be able to determine the optimal deformation regimes: the amount of deformation during compression and unloading of the system, the speed of deformation and energy consumption. The sequence of the analytical study of the mathematical model (1) and the analysis of the deformation process of the viscous-elastic food dispersion system with residual deformation are as follows.

As you know, the formation of food products consists of two stages: compression of the system under the action of a force load and reverse partial expansion after its removal.

The compression process is subject to the law of deformation of the rheological model in the form of the Kelvin body. Let's present it in a classic form. In order to do this, let's simplify the writing of the equation (1). Let's denote the load *P/s*=$\tau$ and rewrite the deformation equation of the Kelvin body in the known rheological dependence:

$$\mu\left(\frac{d}{dt}x(t)\right)+cx(t)=\tau\,, \qquad (6)$$

At the beginning of the deformation, when *x*(0)=0, we will get the solution of the equation:

$$x(t)=\frac{\tau}{c}-\frac{e^{\frac{-c\cdot t}{\mu}}\cdot\tau}{c}\,, \qquad (7)$$

Compression in a cylindrical form of bread crumb with pressure *τ* = 1000...10000 Pa, when its rheological characteristics *μ* = 45000 Pa·s and *c* = 40000 Pa are known, is shown in the 3d graph (Fig. 4).

The 3D graph makes it possible to visually determine the amount of deformation *x*(*t*) at a given pressure value τ. Its analysis allows you to control and regulate the compression process of a visco-elastic dispersed system with known rheological characteristics depending on the duration and magnitude of the load, which are inherent in the design capabilities of the technological equipment for forming.

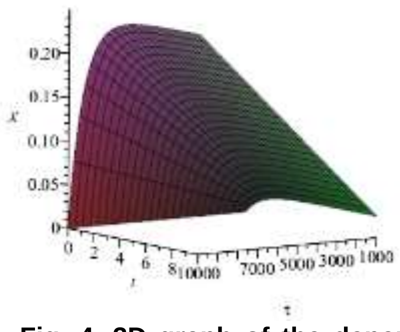


**Fig. 4. 3D graph of the dependence of the relative deformation x(τ,t) of a food product from the pressure τ and duration t of its action**

When using the obtained mathematical dependence (7) in practice, it is necessary to have experimental data of the critical value of the possible maximum relative deformation of the system. For bread crumb, when compressed it in a cylindrical shape, it is equal to $x_1$ = 0.25.

When it is necessary to determine the amount of deformation depending on the duration of compression at a known pressure, using symbolic computer mathematics, the graph *x(τ,t)* can easily be transformed into the form *x(t)*.

At *τ* = 10000 Pa, the *x*(*t*) dependence is shown in Fig. 5.

When the load is reduced to *τ* = 5000 Pa, the relative deformation *x(t)* will decrease (Fig. 6).

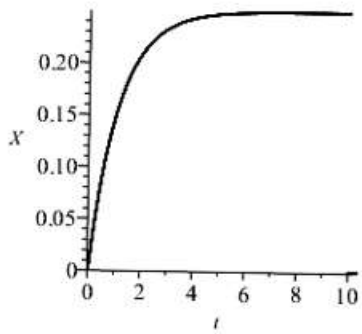


**Fig. 5. Dependence of the relative deformation x(t) at a load of τ =10000 Pa**

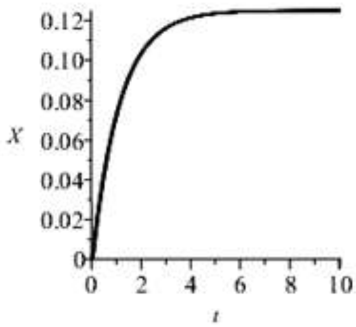


**Fig. 6. Dependence of the relative deformation x(t) at a load of τ =5000 Pa.**

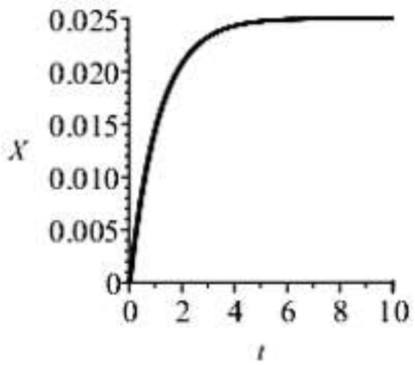


**Fig. 7. Dependence of the minimum relative deformation x(t) at a load of τ =1000 Pa**

According to the results of the experimental studies, the minimum relative deformation was established. At *τ* = 1000 Pa and *t* = 5 seconds, it is equal to *x* = 0.025 (Fig. 7).

The shortcomings of the design of the compression device did not allow to reliably determine the value of the relative deformation $x(t)$ at a low load $\tau \leq 1000$ Pa. The factor of the occurrence of additional resistance forces must be taken into account both when modelling the process of forming of food dispersion systems and when selecting the necessary technological equipment.

An important factor affecting energy consumption in the process of deformation is the speed with which it occurs. The rate of deformation also affects the quality of the finished product. After doing the differentiating of equation (7), we will find it:

$$\frac{d}{dt}x(t) = \frac{e^{\frac{-c\cdot t}{\mu}}\cdot \tau}{\mu}, \qquad (8)$$

3D graph of the dependence of the compression speed of a food product with rheological characteristics $\mu$ = 45000 Pa·s and $c$ = 40000 Pa, from the pressure $\tau$ and the duration t of its action. (Fig. 8).

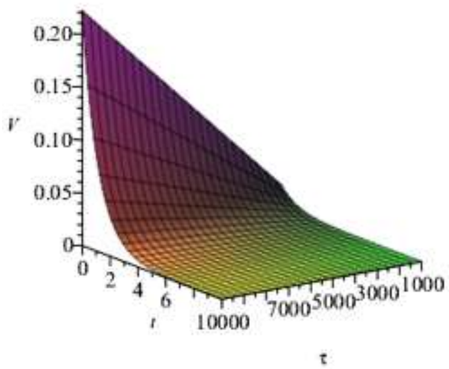


**Fig. 8. 3D graph of the dependence of the deformation speed V(τ,t) of a food product from the pressure τ and the duration t of its action**

Similarly to the previous 3d graph presented in Fig. 4. (dependency of the magnitude of the relative deformation $x(\tau,t)$), if it is necessary to determine the magnitude of the deformation rate $V(\tau,t)$ from the duration $t$ of compression, when the pressure is known, the 3d graph can easily be transformed into the form $V(\tau,t)$.

At pressure $\tau$ = 10,000 Pa, the dependence of *V (t)* is shown in Fig. 9.

At a pressure of $\tau$ = 5000 Pa, the dependence of *V (t)* is shown in Fig. 10.

At a pressure of $\tau$ = 1000 Pa, the dependence of *V (t)* is shown in Fig. 11.

After removing the load, when we have $\tau$ = 0, the reverse process begins. The system gradually returns to its initial state.

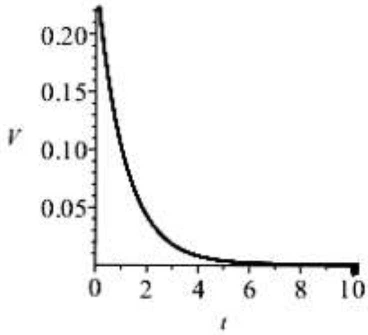


**Fig. 9. Dependence of the deformation rate V(t) of the product from the duration t at a load of τ = 10000 Pa**

Its unloading occurs due to the internal energy accumulated by the spring. We write down the differential equation of system unloading:

$$\mu\cdot\left(\frac{d}{dt}x(t)\right) + cx(t) = 0\,. \qquad (9)$$

Its solution at the initial condition $x(0) = x_1$ will be

$$x(t) = e^{\frac{-c\cdot t}{\mu}}\cdot x_1,, \qquad (10)$$

where $x_1$ is the maximum relative compressive strain known from the load schedule of the system.

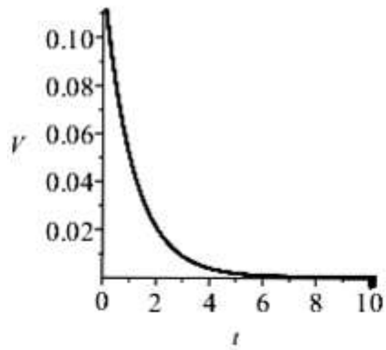


**Fig. 10. Dependence of the deformation speed V(t) of a food product on the duration t at a load of τ =5000 Pa**

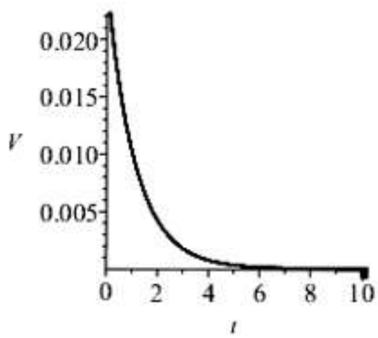


**Fig. 11. Dependence of the deformation speed V(t) of a food product on the duration t at a load of τ =1000 Pa**

The graph of equation (10) of the unloading of the system at the maximum relative deformation $x_1$ = 0.249, which corresponds to the pre-compression pressure $\tau$ =10000 Pa, is presented in Fig. 12.

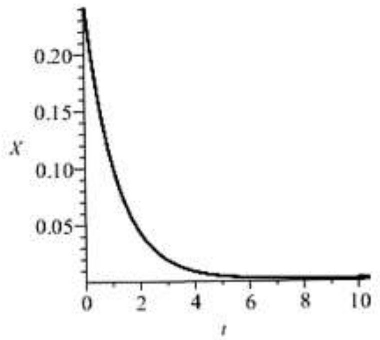


**Fig. 12. Dependence of the relative deformation x(t) of unloading the system at the maximum deformation $x_1$ = 0.249, pre-compression pressure τ = 10000 Pa**

After differentiating the equation (9), we get the speed (dimension 1/*s*) with which the system returns to its initial state.

$$\frac{d}{dt}x(t) = \frac{c \cdot e^{\frac{-c \cdot t}{\mu}} \cdot x_1}{\mu}. \qquad (11)$$

For a food product, when the rheological characteristics of the viscous component $\mu$ = 45000 *Pa·s* and the elastic component $c$ = 40000 Pa, the graph of the dependence of the rate of shape renewal of the pre-deformed visco-elastic product (system unloading) will look like this.

The negative value of the velocity of the unloading system *V*(*t*) characterizes the direction of velocity vector of the system unloading.

The analysis of the graphs of relative deformation *x(t)* and deformation rate *V(t)* shows that the system (formed food products) with different initial loads completely returns to the state of the beginning of the deformation process. This corresponds to the selected rheological model in the form of the Kelvin body, but does not correspond to the real process of deformation of food products, when we have a residual plastic deformation when the load is removed. To determine its value, we will make changes to equation (9).

To determine the residual deformation, the following mathematical dependence was obtained, which allows to calculate its value

$$x(t) = (x_1 - b) \cdot e^{\frac{-c \cdot t}{\mu}} \cdot x_1 + b, \qquad (12)$$

where *b* is the plasticity characteristic of the system, a dimensionless quantity. It is determined analytically-experimentally for each product and deformation conditions.It characterizes the residual deformation after removing the load and stopping the deformation process. For bread crumb, the plasticity *b* characteristic of the system is equal to *b*=0.04.

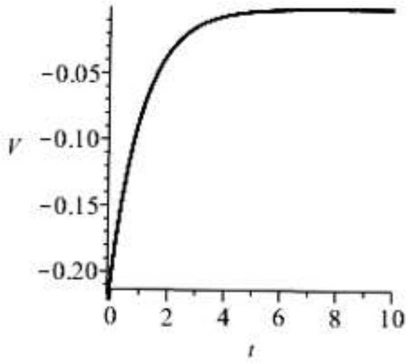


**Fig. 13. Dependence of the system unloading rate V(t) at the maximum deformation $x_1$=0.249, which corresponds to the predeformation pressure τ = 10000 Pa**

The graph of the equation (12) is presented in Fig. 14.

It should be noted that when modelling the unloading process, the values of the rheological characteristics of viscosity and elasticity will differ from those that were when loaded. This is due to a change in the structure of the dispersed phase of the system.

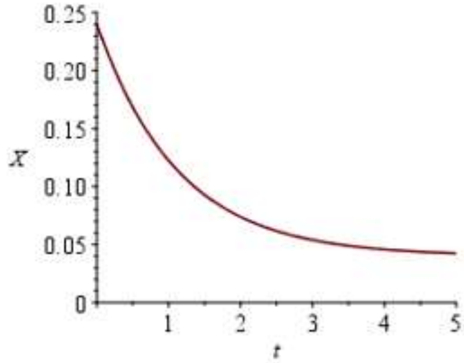


**Fig. 14. Dependence of the relative deformation x(t) of unloading of the system with residual plastic deformation b=0.04 at the maximum deformation $x_1$ = 0.249, pre-compression pressure τ =10000 Pa.**

The more load cycles, the greater the changes in rheological characteristics. The result of a large number of cycles will be heating, loss of elasticity of the system and, as an alternative, grinding to a powdered state, which must be taken into account in the development and implementation of standardized processing modes aimed at preserving the stable properties of food mass in production conditions [17].

**Conclusions.** The mechanism of formation of crushed food products has its own characteristics and is not sufficiently studied. In order to determine the optimal modes of deformation, the amount of deformation, the speed of deformation and energy costs, there are no necessary mathematical models. Due to this, a new method of mathematical modelling of the process of deformation of viscous-elastic food dispersion systems with residual deformation was developed and described in the work. The concept of the term rheodynamics is given and its difference from the term rheology is formulated.

The presented mathematical models and obtained on their basis the results of calculations of the process of deformation

of food dispersion systems can be used to optimize the process of formation of crushed food dispersion systems.

**For the first time:**

The mechanism of formation of food dispersion systems is considered as a two-stage. It consists of successive stages of power loading of the system and its unloading, which corresponds to the process of compression and, accordingly, the reduction of volume, and its partial renewal due to the reverse increase in the size of structured food products. The relationship between deformation, speed, load, rheological properties and duration of the forming process was established.

When modelling the formation of food dispersion systems, the sequence of transition from the known classical rheological regularities and characteristics of the deformation process is revealed, when its duration is measured in seconds, the pressure and elasticity characteristics have the dimension Pa, the deformation is relative and dimensionless, the deformation rate has the dimension 1/s and the characteristic in viscosity Pa·s, to generally accepted engineering. For them, the dimensions $L(t)$ and $L_H$ of the body are determined in meters, the relative deformation $(L_H–L(t))/L_H$ is dimensionless, the deformation speed is in *m/s,* the elasticity of the system and the driving force of the deformation are in Newtons. The introduction of the concept of engineering rheodynamics and the transition to generally accepted engineering methods of modelling of mechanical processes allows to calculate the energy characteristics of the deformation process in quantities where the energy (work) of deformation in N·m = Joule, energy consumption (power) Joule /second = W and to select according to the energy consumption for deformation an electric motor or the other power unit of the required capacity.

**References**

1. Kruglickij, I. N. 1976. Fundamentals of physical and chemical mechanics. Kyiv: Higher school. 116 p. [in Ukrainian].

2. Levit, I. B., Sukmanov, V.O., Afenchenko, D. S. 2015. Rheology of food products. Poltava: PUET. 540 p. [in Ukrainian].

3. Levit, I. B., Sukmanov, V. O., Afenchenko, D. S. 2014. Rheology of food products. Donetsk: DonNUET. 559 p. [in Ukrainian].

4. Ovchinnikov, P. F., Kruglickij, N.N. Mihajlov, N.V. 1972. Rheology of thiscotropic systems. Kyiv: Naukova Dumka. 120 p. [in Ukrainian].

5. Fischer, P., Pollard, M., Erni, P., Marti, I., Padar, S. 2009. Rheological approaches to food systems. *Physique*. (10), pp. 740–750. [in English].

6. Daubert, C. R., Foegeding, E. A. 2003. Rheological principles for food analysis. New York: Kluwer Academic/Plenum Publishers. In S. S. Nielsen (Ed.), *Food analysis* (3), pp. 507–508. [in English].

7. Gipsy Tabilo-Munizagaa, Barbosa-Ca´novas. 2005. Rheology for the food industry. *Journal of Food Engineering*. (67), pp. 147–156. [in English].

8. Cherevko, O. I., Mykhailov, V. M., Maiak, V. I., Maiak, O. A. 2014. Rheology in the production of grubs: Navch. proverb: at 2 hours. Part 1 Classification and characteristics of non-Newtonian natives. University of food and trade. Kharkiv: KhDUFT, 244 p. [in Ukrainian].

9. Cherevko, O. I., Mykhailov, V. M., Maiak, V. I., Maiak, O. A. 2012. Rheology in the processes of production of food products. University of Food and Trade. Kharkiv: KhDUFT, 180 p. [in Ukrainian].

10. Rielly, C. D. 2010. Food rheology. Chemical *Engineering for the Food Industry*. Springer, Boston, MA. pp. 195–233. [in English].

11. McKenna, B.M., Lyng, J.G. 2003. Introduction to food rheology and its measurement. *Texture in food*. Vol. 1. pp. 130–160. [in English].

12. Ton Van Vlie. (2013) Rheology and fracture mechanics of foods. Raton: CRC Press. US eBook. 363 p. [in English].

13. Hencheva, V. I., Lashko, N. P., Brazhko O. A. 2019. The rheology of food grade products. Zaporizhzhya: Zaporizhzhya National University. 74 p. [in Ukrainian].

14. Maryam Maleki, Seyyed Ali Mortazavi, Samira Yeganehzad, Ahmad Pedram Ni. 2019. Effect of basil seed gum, xanthan gum and carrageenan on rheological and sensory properties of suspended barberry pulp in syrup. *Ukrainian Food Journal*. Vol. 8. Issue 4. pp. 840–850. [in English].

15. Guts, V. S., Polyevoda, Yu. A., Tkachuk, I. V., Koval, O. A. 2024. Modeling of the meat salting process in horizontal drums. *Vibrations in engineering and technology.* 2024. N 1 (112). P. 72–80. [in Ukrainian].

16. Guts, V. S., Polievoda, Y. A., Koval, O. A. 2011. Determination of structural and mechanical characteristics of viscosities dispersed systems. *Packaging*. N 1. pp. 46–47. [in Ukrainian].

17. DSTU ISO 22000: 2007 Food safety management systems. Requirements for any food chain organizations (ISO 22000: 2005, IDT).

## РЕОЛОГІЯ У СТАНДАРТИЗОВАНИХ ПРОЦЕСАХ ФОРМУВАННЯ ХАРЧОВИХ ПРОДУКТІВ

*У статті розглядається формування харчових продуктів, зокрема м'ясних, отриманих зі структурованої сировини. Вирішальне значення має якість процесу формування, яка залежить від фізико-механічних властивостей сировини (в'язкість, пластичність, адгезія) та правильного вибору технологічних режимів.*

*Важливу роль у цьому процесі відіграє стандартизація, яка забезпечує єдність вимог до складу сировини, параметрів обладнання та умов виробництва. ДСТУ та міжнародні стандарти ISO встановлюють норми для реологічних характеристик харчових мас, точності формування, санітарних вимог і допусків температурних та механічних навантажень. Дотримання стандартів дозволяє досягти стабільної якості продукту, безпеки та ефективності виробничого процесу.*

*Подальше дослідження процесів формування має ґрунтуватися не лише на фізико-хімічних властивостях маси, а й на вимогах чинних стандартів, які регулюють виробництво харчової продукції в умовах промислового виробництва.*

*Представлені результати теоретичного та експериментального дослідження механізму стиснення концентрованої подрібненої харчової сировини з урахуванням вимог до стандартизації процесів формування продуктів. Для моделювання поведінки харчових мас обрано реологічну модель тіла Кельвіна, яка враховує в'язко-пружні властивості систем. Такий підхід дозволяє формалізувати поведінку продуктів під час деформації відповідно до стандартних технологічних параметрів, передбачених нормативною документацією для м'ясної продукції.*

*Результати дослідження, які показують залежність деформацій від тривалості та умов навантаження, були представлені графічно. Вперше науково обґрунтовано механізм залишкової пластичної деформації та розроблено математичну модель для її розрахунку, що дозволяє враховувати її в системах контролю якості відповідно до чинних стандартів.*

*Такі підходи можуть бути інтегровані в стандартизовані методи контролю та оптимізації процесів формування у харчовій промисловості.*

***Ключові слова**: формування харчових продуктів, деформація дисперсних систем, реологія, математичне моделювання деформації, залишкова деформація, стандартизація, контроль якості.*

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