UDC 637.54.03[66.84.8+66-982]

KINETICS AND ENERGY OF POULTRY MEAT DEHYDRATION IN VACUUM AND MICROWAVE FIELD CONDITIONS

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Abstract. The article presents the results of obtaining dried poultry meat under vacuum conditions using ultrahigh electromagnetic energy sources. A characteristic of the most common principles of drying is presented, which shows that the trends in the technology of drying technology is a reduction of specific energy consumption. From literary sources it is known that this is the best way to preserve meat protein in the native state. This method of drying leads to the release of a large amount of heat, resulting in evaporation can occur at a low temperature. The heat dissipated is spent exclusively on the evaporation of moisture without heating the fabric of the product. The rational modes of microwave-vacuum drying for meat semifinished products are determined. Drying was carried out at a temperature below 40°C and a pressure of 8 kPa with simultaneous processing by an electromagnetic field at a frequency of 2.7 GHz. This contributes to the intensive evaporation of moisture without a significant change in the structure of the surface layer, reducing the length of processing. Microwave-vacuum drying provides high functional and technological properties, namely: moisture-binding ability, water-retaining, fat-retaining ability and mass fraction of residual moisture, and better organoleptic characteristics. According to the sensory evaluation, the samples studied had a more fragile consistency, characterized by dry powders, a pleasant taste and a flavor similar to boiled chicken meat. The article shows the dependence of the mass of condensate on the duration of drying. On the basis of what was determined the duration of drying of the meat additive, which is 3 hours, while the mass fraction of residual moisture is 4.5%. It was established that obtaining dried meat semis from poultry meat under vacuum conditions using ultra high frequency electromagnetic energy sources allows to receive products with less energy and for a shorter period of production.

Key words: microwave-vacuum drying, dried meat, functional and technological properties, residual moisture.

КІНЕТИКА ТА ЕНЕРГЕТИКА ЗНЕВОДНЕННЯ М'ЯСА ПТИЦІ В УМОВАХ ВАКУУМУ ТА МІКРОХВИЛЬОВОГО ПОЛЯ

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Анотація. У роботі досліджено сушіння м’яса птиці в умовах вакууму з використанням електромагнітних джерел енергії надвисокої частоти. Представлено характеристику поширених принципів сушіння, яка свідчить, що тенденції розвитку техніки сушіння – це зменшення питомих витрат енергії. Такий спосіб є найкращим для збереження білка м’яса в нативному стані. Визначено раціональні режими мікрохвильово-вакуумного сушіння для отримання м’ясного напівфабрикату. Сушіння здійснювали при температурі нижче 40°С і тиску 8 кПа з одночасною обробкою електромагнітним полем з частотою 2,7 ГГц. Це сприяло інтенсивному випаровуванню вологи без істотної зміни структури поверхневого шару, зниженню тривалості обробки. Показано залежність утворення маси конденсату від тривалості сушіння, на підставі чого визначено тривалість сушіння м’ясної добавки, що складає 3 години, при цьому масова частка залишкової вологи складає 4,5%. Встановлено, що одержання сушеного м’ясного напівфабрикату із м’яса птиці в умовах вакууму з використанням електромагнітних джерел енергії надвисокої частоти дозволяє одержати вироби з меншими витратами енергії і за менший термін виробництва. Мікрохвильово-вакуумне сушіння забезпечує високі функціонально-технологічні властивості, а саме: вологозв’язувальну, вологоутримувальну, жироутримувальну здатності, вміст залишкової вологи, органолептичні показники. За результатами сенсорної оцінки, досліджувані зразки мали розсипчасту консистенцію, притаманну сухим порошкам, приємний смак і аромат подібний вареному м’ясу курятини.

Ключові слова: мікрохвильово-вакуумне сушіння, сушене м’ясо, функціонально-технологічні властивості.

DOI: http://dx.doi.org/10.15673/fst.v12i4.1218

Introduction. Formulation of the problem

The growing level of production and consumption of poultry meat requires from producers development of more modern and perspective niche of food, expansion of assortment and development of technologies of new products of high quality and nutritional value, resistant to bacterial damage with prolonged storage [1].

In this area, the production of dried meat is perspective, the technology of which allows products with high protein content and mineral components to minimize destructive changes in biological components, which allows to classify them as products of high nutritional value.

The development of dry meat products technologies is associated with the use of new types of meat, the combination of it with plant fillers, the development of innovative methods of drying and packaging products aimed at increasing the consumer properties and hygienic quality of products.

Analysis of recent research and publications

The key to the efficiency of food industry operations is the introduction of resource-saving and competitive technologies. The use of dried meat makes it possible to simplify the operations of mechanical processing of meat raw materials, reduce the length of the process, expand the range and reduce the area of storage and production facilities.

In this regard, the development of the technology of dried meat semis is an urgent task.

Developments of domestic and foreign scholars such as Snezhkina Yu.F., Gulyaeva SP, Zhuravskaya N.K. and others confirmed the relevance of dried meat production [2].

Chinese scientist Nguyen Hiu Zi proposed a method of producing a dried meat product from bone-in meat, where the key was the mechanical change of the structure of the meat fibers.

Scientists from Algeria Ahmed Mediani, Akil Loumani and others. examined dried meat from a camel, drying was carried out using a solar dryer. Specialists of the Mongolian Institute of Veterinary Medicine have been invited to obtain roughage from meat raw materials, which includes drying and slicing [3].

Fidel Toldrá from Spain investigates dried meat delicacies (ham). Scientists O.A. Popov, VA Smirnov and others received dried chicken minced meat with improved taste and smell and longer shelf life. Hussein M.H.Mohamed is researching traditional dried meat products. Researchers from the State Agricultural University of Russia conducted a range of researches with the help of which the optimal conditions for providing the maximum hydration properties to dried meat were determined [4].

Specialists of the Voronezh State Technological Institute proposed a way to restore dried meat by sublimation by soaking it in saline solution with proteolytic enzymes or 1–2% starch solution.

Snezhkin Yu.F. and others from the Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine have developed a technology for the production of dried meat based on a convectional method of drying using cooking and grinding of meat before it is dried. The product obtained by convectional drying is characterized by increased rigidity, which negatively affects organoleptic quality indicators, and makes it impossible to be used for the preparation of a number of meat products [5].

By scientists Antipov AV, Baybuz V.N. and Grudinkin Yu.V. the method of sublimation drying of pieces of meat is developed, which includes immersion at a depth of ¾ from the height of their pieces in a liquid, warm environment and freezing the pieces of the product. At the pre-drying stage, the coolant is thawed and until the meat drying, the coolant is in a liquid state. The total drying time is 18 hours [6].

There is known method for obtaining a dried meat semifinished product with mixed heat supply. The peculiarity of this method is the creation of special conditions for the interaction of dehydrated material with a drying agent – air, reducing energy consumption and the duration of the process, but the meat is dried at a temperature of 60–70°C [7].

Efforts of the majority of scientists in the field of drying are directed to experimental modeling of processes, development of methods for calculating kinetics of drying. The tendency of increasing restrictions in model types of objects and products has been determined. The justification was to increase the accuracy of the model. Finally, regression models that describe experimental data arrays began to be used. The accuracy of such models was determined by the errors of the experimental data, the capabilities of the mathematical apparatus and turned out to be quite acceptable for engineering tasks. However, these models are valid only for experimental conditions and for the investigated object, i.e. do not extend to the class of even similar problems, can not be used to set prediction and optimization tasks even for the investigated apparatus. Thus, the theory of drying can not effectively use the vast volume of experimental material. Common models are not exact, and precise regression models can not give any new information.

It seems that the problems that have arisen at the describing the process of drying are due to the fact that all authors, proponents of the phenomenological approach, consider drying as a single process with constant transport coefficients and form models basing on these assumptions.

Currently, the theoretical basis of drying processes is the fundamental model of O.V. Likov [8]. However, it does not take into account the position of Rabinder on the forms of connection moisture in the raw material. For such a contradiction, it is proposed to supplement the system of O.V. Likov equations, taking into account the fields of moisture on the surface (Up), in capillaries (Uk) and absorption separately (Ua).

Thus, a lot of scientists were engaged in the drying of meat, mainly for its use as an independent food product, without emphasizing its functional and technological properties. Therefore, the development of the technology of dried meat semis is an urgent task.

The purpose of this work was to study the process of drying meat supplements for culinary products, which will allow to obtain new products of high quality and nutritional value, to be guaranteeing the safety of the product with a significant reduction in energy costs. To achieve this goal it was necessary to solve the following **tasks**:

- analyze existing methods of obtaining dried meat; - to determine the optimal modes of microwave-vacuum drying for the meat additive; - to investigate functional and technological and organoleptic properties; - to determine the electricity consumption of the obtained dried meat additive.

Research materials and methods

As subjects of research the following were used: the fillet of poultry meat (sample 1) and meat of mechanized bird collapse (sample 2) which were subjected to microwave-vacuum drying. The slices of meat were dried at a temperature of 31–37°C under vacuum conditions at 7.5–8.0 kPa with simultaneous processing by an electromagnetic field at a frequency of 2.7 GHz for 3 hours to a residual moisture of 4.5%. The following research methods were conducted: sensory studies, functional-technological (determination of moisture content, water-absorbing ability, water-retaining capacity, fat-retaining ability**)** and economical ones [9].

The production of dried meat additives was carried out at the Department of Processes, Equipment and Energy Management of the Odessa National Academy of Food Technologies.

The process of drying. Experiments were carried out in a sealed reactor made of radio-transparent material (glass). Vacuum in the chamber is provided by a membrane vacuum pump. The reactor is placed in a chamber with a microwave energy source. The vapor volume of the chamber was connected to a condenser, where cold water was circulating. The steam was converted into condensate, and the condensate mass was determined using digital weights. By mass of condensate raw materials moisture content was established. The temperature of the reactor was measured using a pyrometer of radiation, and the pressure in the chamber – by an exemplary vacuum sensor. Power consumption was determined using a voltmeter counter.

Determination of moisture content. The moisture content of the protein component was determined by drying the crushed sample at a temperature of 150°C for 1 hour. The mass fraction was determined as the difference between the weight of the drying unit (A1) and after drying (B) to the weight of the weight gain (A), expressed as a percentage:

$$W = (A_1\text{-}B)/A\times100 \qquad (1)$$

Determination of water-absorbing ability. The water-binding ability of meat was determined by the Grau and Hamma method. A weight of the mass of 0.3 g, weighed to 0.0001 g precision on a polyethylene with a diameter of 55-60 mm is transferred to an ash-free filter, which is placed on a Plexiglas plate 100×100 mm in size. The hard cover is covered with another plate of the same size and a load of 1 kg is placed on top. The pressing lasts for 10 minutes, after which the contour marks the spots around the pressed meat. The area is measured by a planimeter in cubic centimetres. The content of bound water in meat is calculated by the formula:

$$V = (A\text{-}K\times B)/M\times10 \qquad (2)$$

A-water content in weight, mg; K=8.4 mg; B – area of a wet spot, cm^2, M – the mass of weight meat, mg.

Determination of water-retaining capacity. The protein component is hydrated in distilled water at a ratio of 1:5 for 1 hour, then it is placed in a thermostat with a temperature of 74–76°C and kept for 15 minutes. The contents of the glasses are transferred to centrifuge nets and centrifuged for 15 minutes at 1000 rpm for separation of unbound water. It is calculated as the difference between the mass of the hydrated texture (Mr) and the mass of dry (Ms) to the mass of dry texture (Ms), expressed as a percentage:

$$WRA = (Mr\text{-}Mc)/\ Mc\times100 \qquad (3)$$

Determination of fat-retaining ability. The protein component is dispersed in 10 g of vegetable oil and for 1 h at 20°C, then placed in a thermostat with a temperature of 74–76°C and kept for 15 minutes. The contents of the glasses are transferred to centrifuge mesh and centrifuged for 15 minutes at 1000 rpm [33]. Calculated as the difference between the mass of the dispersing texture (Mr) and the mass of dry (Ms) to the mass of the dry texture (Ms), expressed as a percentage:

$$FRA = (Mr\text{-}Mc)/\ Mc\times100 \qquad (4)$$

Sensory evaluation. For sensory analysis, a commission of 5 people was formed. The research was carried out according to the following order: at first the outer look of the additive was evaluated. Then evaluated: the consistency, structure, dry measures, smell. In the study of color, attention was paid to the homogeneity, property, the absence of undesirable changes in color – darkening, etc. Sensory analysis was conducted on a 10-point scale.

Results of the research and their discussion

It has been established that one of the ways of preserving meat protein in the native state is drying at low temperatures, namely the use of microwave-vacuum drying. Such drying leads to the release of a large amount of heat, which is spent solely on the evaporation of moisture without heating the fabric of the product, resulting in evaporation that can occur at a low temperature. This contributes to the intensive evaporation of moisture without a significant change in the structure of the surface layer, reducing the length of processing, preservation of biologically active components of raw materials, dying of microbial cells and inactivation of enzymes [10].

In the process of work the method of drying poultry meat in vacuum with the use of ultra high frequency electromagnetic energy sources to provide products with high functional and technological properties, such as: water-binding, water-retaining, fat-retaining capacity, with lower energy consumption and for a shorter term of work, was used [11-12].

Critical analysis of the literature made above, makes it possible to draw the following conclusions.

1. The lack of a systematic approach to the study of energy technology problems, and the experience in solving energy efficiency problems are exacerbated by the energy crisis [13]. This is to a large extent related to drying technology [14].

2. In food and processing industries drying, as a rule, determines both the cost price and the quality of the product. The most widespread here were convective drying methods, which are characterized by serious scientific and technical contradictions. The desire to achieve high coefficients of heat and mass transfer requires an increase in the velocity of the heat carrier, i.e. its expense However, at the same time, losses of heat with exhausted drying agent increase proportionally and that in the conditions of the energy crisis is undesirable [15,16].

3. In the conditions of the energy crisis, the stable growth of the cost of energy carriers, the energy and environmental concepts of drying need to be reconsidered [17].

The paper formulates the hypothesis that drying is the result of action on the principle of superposition of 3 processes (Fig. 1). In addition, some modern technology samples extract moisture not on the basis of the classical diffusion mass transfer. Therefore, the authors use a more general term – dehydration. In accordance with the formulated hypothesis (Fig. 1), the graph of the thermovalentransference (Fig. 2) and the system of O.V. Lykov's equations are developed.

Self-examination of surface moisture, U_P, capillary moisture, U_k and absorbtion-bound moisture, U_A (Fig. 2).

In accordance with (Fig. 2) the system of O.V. Lykov's equations is developed:

The system of equations (5) is more complicated than the traditional system of O.V. Likov. However, it allows us to substantiate the hypothesis of a superposition of the action of several processes when dehydrated. Each of these processes is characterized by its value of the driving force and the kinetic coefficient of the process speed. The processes themselves are subject to their transfer laws and are implemented at the expense of different mechanisms (Table 1).

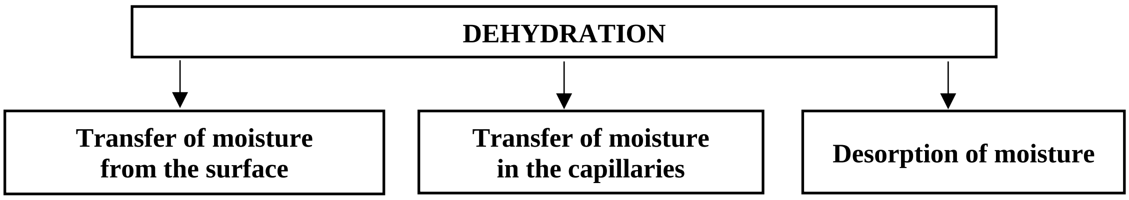


Fig.1. Structural diagram of processes at dehydration

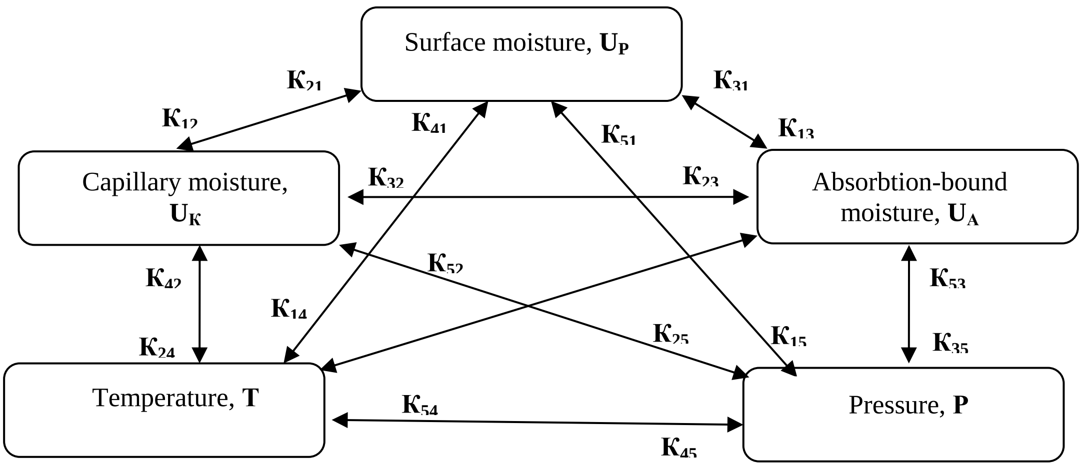


Fig. 2. A graph of connected processes of dehydration

$$\left.\begin{aligned}
\frac{\partial U_P}{\partial \tau} &= K_{11}\nabla^2 U_P + K_{12}\nabla^2 U_K + K_{13}\nabla^2 U_A + K_{14}\nabla^2 t + K_{15}\nabla^2 P \\
\frac{\partial U_K}{\partial \tau} &= K_{21}\nabla^2 U_P + K_{22}\nabla^2 U_K + K_{23}\nabla^2 U_A + K_{24}\nabla^2 t + K_{25}\nabla^2 P \\
\frac{\partial U_A}{\partial \tau} &= K_{31}\nabla^2 U_P + K_{32}\nabla^2 U_K + K_{33}\nabla^2 U_A + K_{34}\nabla^2 t + K_{35}\nabla^2 P \\
\frac{\partial t}{\partial \tau} &= K_{41}\nabla^2 U_P + K_{42}\nabla^2 U_K + K_{43}\nabla^2 U_A + K_{44}\nabla^2 t + K_{45}\nabla^2 P \\
\frac{\partial P}{\partial \tau} &= K_{51}\nabla^2 U_P + K_{52}\nabla^2 U_K + K_{53}\nabla^2 U_A + K_{54}\nabla^2 t + K_{55}\nabla^2 P
\end{aligned}\right\} \qquad (5)$$

The proposed hypothesis does not contradict the fundamental ideas of the physics of a moist capillary porous body. The scheme of the forms of moisture communication by P. A. Rebinder is generally accepted. The removal of moisture from various forms of communication are different processes with their transfer coefficients, with their potential, driving force (Table 1). Acceptance of the motive force correction using the water activity indicator $\boldsymbol{a_i}$ is known.

As to the drying technology, it often develops faster than theoretical foundations. Along with the traditional conductive and convective, the principles of filtration [17] and drying with combined heat approach appeared [18] (Table 2).

Table 1 – Characteristics of the main processes when dehydrated

No	Process	Process Mechanism	Process Motive Force	Kinetic Coefficient
1	The removal of moisture from the surface	Convective Diffusion	$A_kP_p - P_v$	β_k
2	The removal of moisture from capillaries and pores	Convective Diffusion in Restricted Conditions	$A_cP_p - P_v$	β_c
3	Desorption of moisture	Convective Diffusion	$A_dP_p - P_v$	β_d

Table 2 – Characteristics of traditional principles of drying

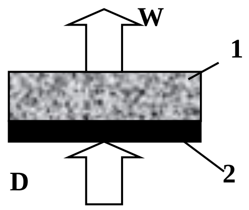
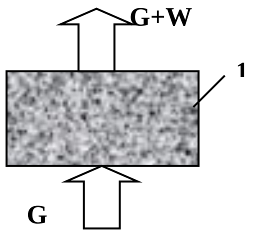
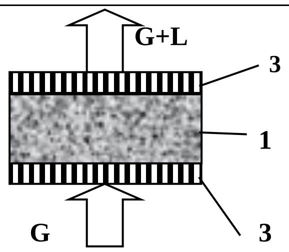
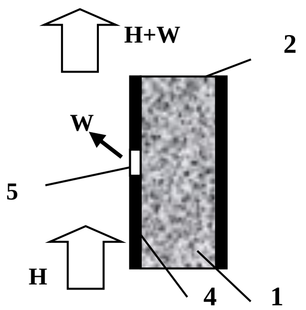
Type of drying	Advantages	Scientific and technical contradictions
 **Conductive**	– minimal energy costs due to the absence of coolant emissions; – the possibility of using different types of fuel, energy; – absence of direct contact of the coolant with the product.	- the intensity of heat and moisture transfer is determined by the thickness of the product layer, which limits both productivity and constructive solution
 **Convective**	– simplicity of design for mine, chamber, drum, tape, etc. types; – no performance constraints; – possibility of stationary and mobile use; – the possibility of dehydration of liquid, disperse and solid products.	- the intensification of heat and moisture transfer requires an increase in the velocity, ie, the cost of the coolant, which leads to an increase in energy losses with the exhaust coolant.
 **Filtering**	– possibility of dehydration due to mechanical driving forces; – possibility of dewatering by cold flow of gas; – minimum energy consumption for dehydration.	- the principle effectively removes surface moisture, but it is not able to influence intradiffusion resistance and requires powerful hydraulic machines.
 **Drying with combined heat approach**	– possibility of dehydration with a moist coolant; – low energy consumption for dehydration; – the possibility of recycle of waste heat-carrier.	- the principle of organizing a directed vapor output from raw materials without the presence of air in it requires a complex design and is limited to the type of raw materials.

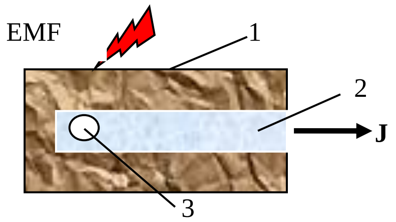
Table 2 shows that the trends in the technology of drying technology is a reduction of specific energy consumption. It is actively looking for ways to abandon energy-consuming convective dryers, their time seems to have passed. The demand for dryers with electromagnetic energy sources is currently in circulation. However, their theoretical foundations are almost absent [19,20].

Consider the features of dehydration in the electromagnetic field. On the elementary volume of fluid in the intercellular space (in the capillary of the raw material) there are forces: A – interaction with the surface of the capillary; I – flow inertia; G – gravity; S – viscosity. The balance of the forces of these forces will determine in which direction and at what speed the component will move. The task of intensifying the processes of mass transfer is to initiate the flow of I. Other forces inhibit the process. In accordance with the Fick equation, a non-stationary three-dimensional field of moisture concentrations has the form (6). The first term in (6) characterizes a purely diffusion transition, the process is traditionally inertial. The proposed concept is based on the potential possibilities of the second term in (2). These changes in the concentration field are due to the release of moisture from the capillary at rate *w*, the value of which depends on the value of the pressure jump ΔP from (7). The connection between these parameters is expressed from the equation of the hydraulics of the capillary system with the length of the channels (l), their diameter (d), the coefficient of friction (λ) and the sum of local hydraulic resistance (ζ). In equation (7), in contrast to the classical recording, the forces of surface tension (σ) are taken into account in connection with the small values of the diameter of the capillaries.

Consider the physical model (Fig. 3) of the system "solid phase - moisture - capillary - electromagnetic field". When using the electromagnetic field (Fig. 4), in the capillary there is a dissipation of the field energy into heat.

$$\frac{\partial U}{\partial \tau} = D\left[\frac{\partial^2 U}{\partial X^2} + \frac{\partial^2 U}{\partial Y^2} + \frac{\partial^2 U}{\partial Z^2}\right] + \left[\frac{\partial U}{\partial X} w_X + \frac{\partial U}{\partial Y} w_Y + \frac{\partial U}{\partial Z} w_Z\right] \quad (6)$$

$$\Delta P = \frac{\rho w^2}{2}\left[\frac{\lambda l}{d} + \sum \zeta\right] + \rho g l + \frac{\sigma}{d} \quad (7)$$



1 – solid phase; 2 – wet;
3 – steam bubble;
EMF – electromagnetic field;
J – steam and moisture stream

Fig. 3. Physical circuit of the cell

Polar moisture molecules in the conditions of an electromagnetic field of ultrahigh frequency pass into a mode of oscillation. There is dissipation of electromagnetic energy in heat. The elevated electromagnetic energy (Nητ) is spent on increasing the internal energy when the heat capacity changes, and on the water to steam transition. As a result, there is increased pressure in the capillary [21]. Moreover, this increase in pressure can be explosive because of the small volume of liquid in the capillary and the concentration of energy:

$$P(\tau) = Pa + \Delta P \quad (8)$$

It is this jump of pressure that causes barodiffusion [22-24]. In this case, significant changes will occur in the formation of the field of moisture concentrations in the system.

The determining factor in the occurrence of barodiffusion is the temperature at the local point of raw material volume. The non-stationary field of temperature taking into account the action of EMF is determined in the form:

$$\frac{\partial t_1}{\partial \tau} = a_1\left(\frac{\partial^2 t_1}{\partial r^2} + \frac{1}{r}\frac{\partial t_1}{\partial r} + \frac{1}{r^2}\frac{\partial^2 t_1}{\partial \varphi^2} + \frac{\partial^2 t_1}{\partial z^2}\right) + \frac{N\eta}{V_1 c_{1V} \rho_1} \quad (9)$$

The influence of EMF is expressed in (8) as an action of the internal energy source by the power (N) and with the efficiency (η).

In the field of electromagnetic radiation, the energy equation has the form:

$$c\rho_0 \frac{\partial t}{\partial \tau} = div(\lambda grad t) + r\gamma\rho_0 \frac{\partial U}{\partial \tau} + N_Э \quad (10)$$

In ratios (5) - (9): c - specific heat capacity; λ - coefficient of thermal conductivity; a - coefficient of temperature conductivity; σ - coefficient of surface tension; ρ - is the density of the dry part of the product; r - heat of phase transition of water into steam; γ - the proportion of water that has become steam; N_e - is the volume density of heat sources (corresponding to the absorption of EMF), τ - is the operating time; z, r, φ - coordinates.

Analysis of wet transfer kinetics is related to the removal of surface and capillary moisture:

$$\frac{\partial U_P}{\partial \tau} = div\left(D_P gradU_P\right) \quad (11)$$

$$\frac{\partial U_K}{\partial \tau} = div\left(D_T gradT + D_B gradP_K\right. \quad (12)$$

hypotheses where, D_P, D_T, D_B –coefficients, respectively, of convective diffusion, thermodiffusion and barodiffusion.

Scientific have been tested in testing equipment that implements appropriate means of addressing energy delivery technologies 17,24].

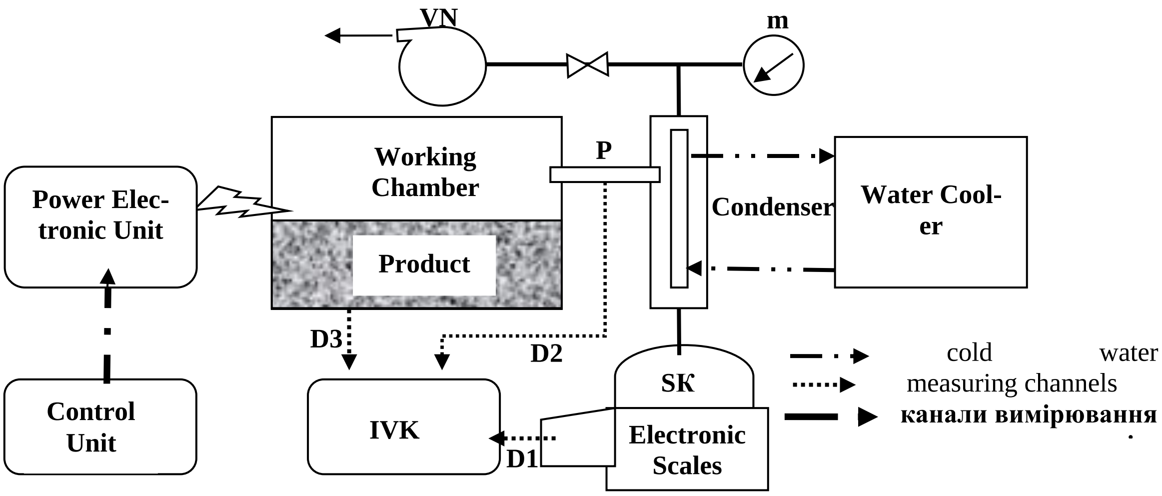


Fig. 4. Stand for research on dewatering processes in the microwave field

Steam volumes of the working chamber and the condenser (KD) are connected by a steam line (n), vacuum control in the system is carried out by an exemplary vacuum gauge (M). The supply of electromagnetic energy is carried out by the power electronics unit (BSE) by the command of the control unit (BU), which contains a timer and a power regulator. The water cooler (VDO) consists of a steam-compressor refrigeration machine, a tank with cooling water, a water temperature regulator and a circulation pump, which provides the supply of cold water to the condenser (KD). The computerized stand, the current information from the electronic scales (EV), the meter of the steam outgoing temperature and the product in the evaporative chamber via the interface is received, recorded and processed by the processor. The stand used electronic scales such as TVE-0,21-0,01 and temperature sensors such as Dallas DS 18b20. The information was collected on a CHUWI CW1506 laptop or tablet. The developed program included the display of thermograms on the screen, the loss of moisture from the camera and the instantaneous values of the rate of removal of moisture (% per minute).

In the experiments recorded: consumption power (N), pressure in the chamber (P), product temperature (T) and steam output (W). The current values of W were determined by the indication of electronic weights (by weight of condensate in the collection). Thus, the output of steam was determined with high accuracy. The operating temperatures did not exceed 50°C. Typical dependencies for 2 types of product are shown in Fig. 5.

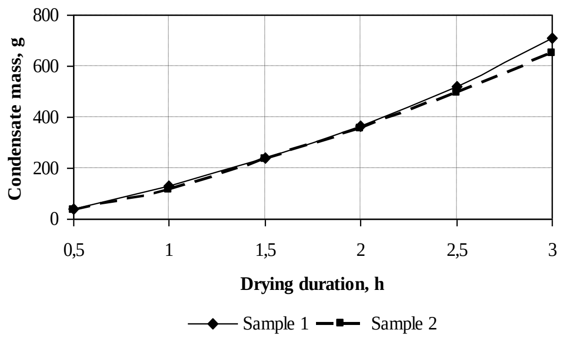


Fig.5. Dependence of the mass of condensate on the duration of drying

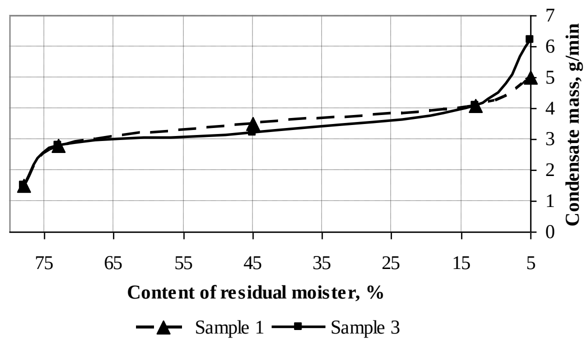


Fig. 6. Vapor-performance of the machine

Drying parameters: P– 8 kPa, frequency – 2.7 GHz, t – 35°C

It is evident that sample 1 gives better moisture (Fig. 5). The results (Fig. 6) shows that the vapor productivity of the installation is practically not reduced throughout the range of moisture content.

Subsequently, pieces of meat, dried in such a way were ground to a powdered state. From 2 kg of meat of mechanized bird collapse received 650 g of dry meat powder (sample 2).

Table 3 shows examples of preparation of dried meat semifinished products of meat of mechanized bird collapse and shows how physico-chemical parameters change from the parameters of the drying process.

Based on the data obtained from Table 3, Example 1 was selected. After all, it provides high functional and technological properties and lower costs of electricity.

Sensory evaluation was performed on 6 main indicators, the results are presented in Fig.7

Table 3 – Examples of obtaining dried meat products from poultry meat and physical and chemical parameters

Examples	Temperature, t, °C	Pressure, P, kPa	Mass fraction of residual moisture,%	Moisture binding ability,%	Water-retaining ability,%	Fat-retaining ability,%	Electricity consumption, kWh / kg of recovered moisture
1	35	8	4.5	46	37	20	0.8
2	37	8	4	44.5	37	19.5	0.8
3	33	7.5	6.5	43	36	16.5	1
4	31	7.5	8	40	35.5	15	1.5
5	41	8.5	3	35	33	14	0.85

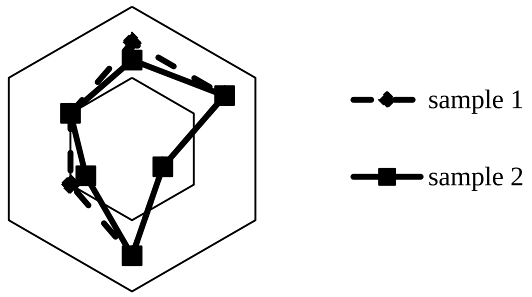


Fig.7. Profilogram of dry meat powder

According to the sensory evaluation, the samples studied were characterized by rather high organoleptic parameters: loose consistency, inherent in dry powders, white color homogeneous with yellowish tint, pleasant taste and smell like boiled chicken meat.

Full system analysis of the proposed technology is complemented by energy indicators [25]. It is necessary to determine the specific energy consumption for dehydration of 1 kg of product (j, kJ/ kg). The energy balance takes into account the heating of the dry part of the meat (Q_C) and the moisture (Q_U), the transition to a couple of particles (γ) of the liquid (Q_Z), heat transfer with the environment (Q_O), and absorption of electromagnetic radiation (N_e): $Q_C+Q_U+Q_z+Q_O+N=0$. Or:

$$G_C c_{P_C}\left(\Delta t_{\Pi_i}\right)+G_U c_{P_U}\left(\Delta t_{\Pi_i}\right)+r\gamma G_U+Q_O+N_Э b\delta_\Pi l_i=0 \qquad (13)$$

The flow of moisture from the product consists of convective (J_K), thermodiffusion (J_T) and barodiffusion (J_B) streams with appropriate mass transfer coefficients (β_K, β_T, β_B), phase contact surfaces (F_i, F_{Ki}, F_{Bi}) and partial pressure differences (ΔP_P, ΔP_T, ΔP_B):

$$J = J_K + J_T + J_B = \beta_K F_i (\Delta P_P) + \beta_T F_{Ki} (\Delta P_T) + \beta_B F_{Bi} (\Delta P_B) \qquad (14)$$

The feature of the proposed equipment is that it uses an expensive resource – electric energy [25]. Therefore, we determine the efficiency of the primary source – fuel (Fig.8).

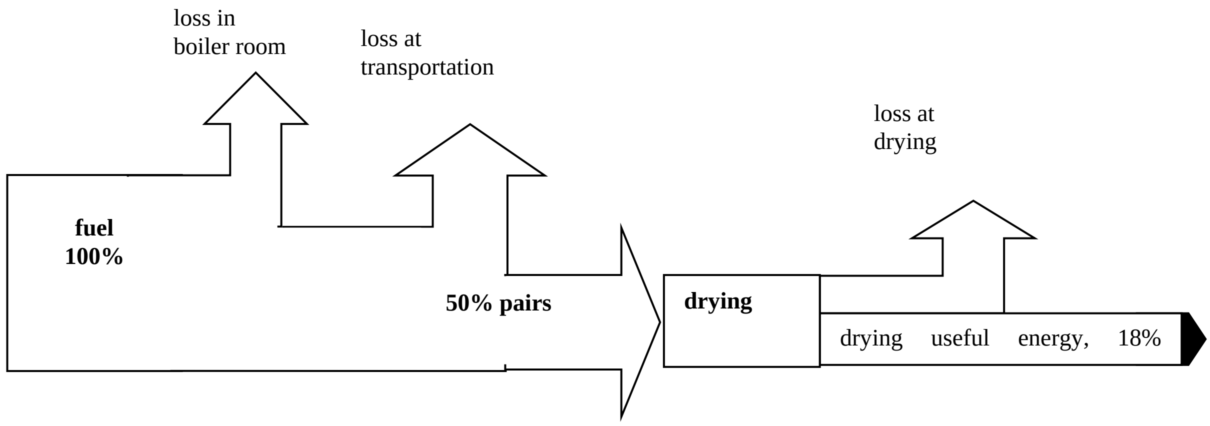


Fig.8. Conversion of energy in traditional convection drying technology

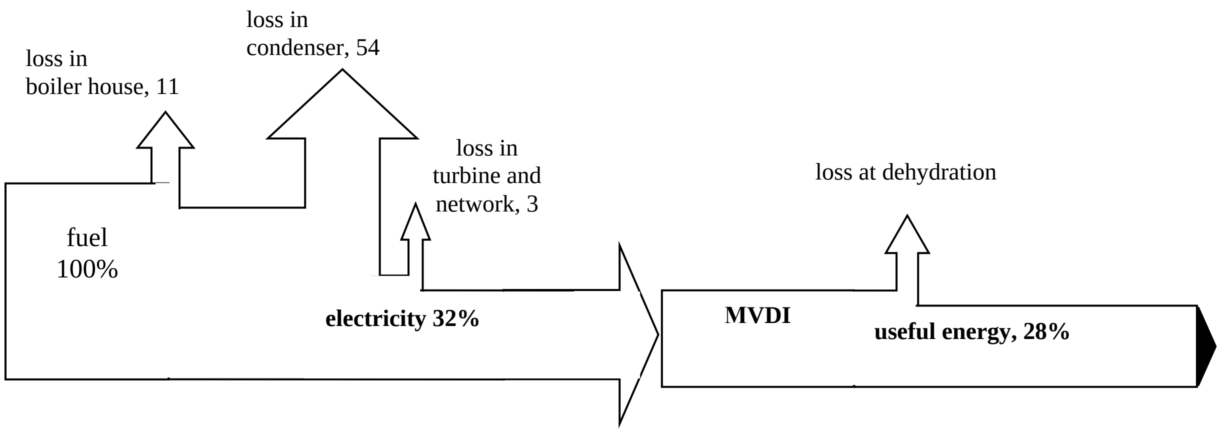


Fig.9. Conversion of energy in an innovative dehydration technology

The comparison shows that the innovative dehydration technology uses fuel energy 1.5 times more efficiently. Such a comparison principle does not depend on current market prices for energy and gives an objective conclusion about energy efficiency. Often, the main priority is the maximum preservation in the finished product of the food potential of raw materials. In this case, traditional drying can not compete with the proposed MVDI (microwave-vacuum drying installation) scheme.

Conclusions

1. Based on the analysis of scientific and technical literature, existing methods of meat drying have been analyzed, the relevance of the formation of the given technological properties for its use in culinary readiness technologies has been proved.

2. The choice of the method of meat drying is proved – microwave-vacuum drying. It has been established that the rational drying regime is a temperature of 35 °C and a pressure of 8 kPa for 3 hours to a residual moisture of 4.5%.

3. Sensory and functional-technological indicators (water-binding, water-retaining, fat-retaining ability) are determined.

4. It was established that the production of dried meat semifinished product of poultry meat, in which, by conducting the process in a vacuum with the use of electromagnetic energy sources of ultrahigh frequency, provides products with lower energy consumption and for a shorter term of work.

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Отримано в редакцію 09.07.2018 Received 09.07.2018
Прийнято до друку 06.11.2018 Approved 06.11.2018

Цитування згідно ДСТУ 8302:2015

Burdo O., Povarova N., Melnyk L. Kinetics and energy of poultry meat dehydration in vacuum and microwave field conditions // Food science and technology. 2018. Vol. 12, Issue 4. P. 117-127 DOI: http://dx.doi.org/10.15673/fst.v12i4.1218

Cite as Vancuver style citation

Burdo O, Povarova N, Melnyk L. Kinetics and energy of poultry meat dehydration in vacuum and microwave field conditions. Food science and technology. 2018; 12(4): 117-127. DOI: http://dx.doi.org/10.15673/fst.v12i4.1218