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DETERMINATION OF OPTIMAL TECHNOLOGICAL PARAMETERS OF FUNCTIONAL MEAT AND FISH MINCED SEMI-FINISHED PRODUCTS

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ВИЗНАЧЕННЯ ОПТИМАЛЬНИХ ТЕХНОЛОГІЧНИХ ПАРАМЕТРІВ ФУНКЦІОНАЛЬНИХ М'ЯСНИХ І РИБНИХ ПОСІЧЕНИХ НАПІВФАБРИКАТІВ

***Objective** is theoretical substantiation and experimental determination of optimal technological parameters of functional meat and fish chopped semi-finished products.*

***Methods**. Meat and fish minced products, two- and three-time grinding, containing 20%, 25% and 30% of the functional additive were selected for the research. The range of variation in the additive content is chosen based on the preliminary organoleptic evaluation of semi-finished products and finished products. Each experiment was carried out in triplicate, and the measurement error of the recorded values (temperature differences) was 5%, provided by a high-precision potentiometer EZ-9. When calculating the amount of moisture, the accuracy of measuring the mass of moisture in the sample in absolute units was* $\pm 0.5 \times 10^{-3}$ *kg. The weight of the studied samples was from 20 to 25 g, which provided sufficient sensitivity in the experiment regarding the process of crystallization of the aqueous phase of the products. The temperature in the thermostat (environment) was maintained at a constant -18 °C. Lines recorded by a continuous automatic potentiometer were digitized using the Grafula 3 software, and then approximated by a polynomial function of the 5th degree in the Mathcad environment. The approximating function was differentiated to determine the inflection points on the curve and to determine the limits of integration when finding the area under the section of the curve that corresponds to the freezing of water in the sample. The technique is based on a low-temperature calorimetric method of measuring the amount of heat released during freezing of free moisture in food raw materials.*

***Results**. The thermophysical properties of model chopped masses based on meat and fish with a functional additive were studied. The influence of the grinding frequency and additive concentration on the ratio between frozen (free) and non-frozen (bound) water was determined. The optimal technological parameters for the production of semi-finished products have been determined. It has been established that the functional vegetable additive in minced meat and fish products contributes to the increase in the proportion of unfrozen moisture at temperatures up to -18 °C. With two-fold grinding, the rational value of the additive should be considered 25%, and with three-fold grinding — up to 30%. In the latter case, the factor limiting the introduction of the additive is the organoleptic indicators of the finished products while maintaining the high moisture-retaining capacity of the semi-finished product.*

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***Key words**: model minced masses, functional plant additive, thermophysical properties, frozen moisture, technological parameters.*

Formulation of the problem. One of the ways to solve the problem of creating new products of increased nutritional value is to combine animal raw materials with raw materials of vegetable origin, which allows to obtain products with a high content of animal protein, enriched with natural biologically active compounds. Among the variety of combined products, chopped meat and fish masses are of particular interest to scientists, adjusting their composition through the introduction of plant additives allows expanding the consumption of non-traditional plant raw materials in food in the form of traditional culinary products for consumers.

In today's unfavorable environmental conditions, medical and biological requirements for the chemical composition, biological and functional properties of food products cannot be sufficiently satisfied without the use of non-traditional ingredients — carriers of certain specific therapeutic and preventive properties. Therefore, the most important problem today is the search for promising sources of raw materials, the development of methods of their processing and use in food, as well as the study of the biological value of new products and the specifics of their impact on the human body. In this aspect, Jerusalem artichoke deserves the special attention of scientists, which, thanks to the content of biologically active substances, has antitoxic, antistress, adaptogenic, immunostimulating and other types of biological activity, for which it is considered a valuable component of dietary and medical nutrition.

The theory of functional nutrition requires a new approach to the development of technologies of functional products, which is based on professional knowledge of nutrientology [1]. The justification and creation of products containing functionally interdependent ingredients of different nature and structure should be based on reliable facts about their functional impact (taking into account synergistic and complex action) on the metabolic and regulatory functions of the body.

Among the variety of products for mass consumption (as objects of enrichment), chopped meat and fish masses are of particular interest to scientists, the technologies of which allow introducing plant additives into their composition [2]. This makes it possible to expand the assortment of cut products and give them the status of functional products.

Both domestic and foreign scientists are dealing with the problem of developing technologies for combined chopped semi-finished products with the use of plant additives. The analysis of literary sources on this issue shows that among the main requirements for the quality of combined products, the optimization of the main parameters of the technological process of the production of combined products occupies a special place.

Analysis of recent research and publications. A significant volume of theoretical and practical research on the study of the technological properties of combined minced food products is reflected in the scientific works of leading scientists of Ukraine and foreign countries: M. I. Pogozhih, M. O. Yancheva, M. G. Gaparova, A. F. Doronin , F. Bellisle, A. T. Diplock, G. Hornstra, P. M. Verschuren and other scientists.

Despite the availability in the research literature of a large amount of information [2, 8—14] regarding the effect of freezing-thawing on meat raw materials, including chopped meat, the absolute values of its physicochemical, thermophysical and other indicators are within wide limits (due to the use raw materials with an individual chemical composition and the use of different methods of freezing), and without experimental determination cannot be used to assess the course of phase and phase-structural transformations.

It is known that during freezing of meat and its storage at low temperatures, a whole series of physico-chemical phenomena takes place in it: freezing of moisture, crystal formation, structural changes in tissues [3].

According to [4], the process of moisture freezing is a process of liquid transformation into crystals, and its essence is expressed in the transition of moisture from a liquid to a solid crystalline substance. For such a multicomponent system as tissue fluid, this process is quite complex. Unlike pure water, the freezing point (cryoscopic point) of such a solution is lower than 0° C and corresponds to its ionic and molecular concentration. Meat juice begins to freeze at temperatures of –0.6° C...–1.2 °C [5]. The freezing of water from the intercellular fluid leads to the formation of hypertonic solutions, the concentration of which increases all the time in accordance with the decrease in temperature [6]. This process continues until the concentration of substances dissolved in the liquid phase reaches the concentration of the lowest point — the so-called eutectic freezing point, which for muscle tissue is in the range –59° C...–64 °C [7].

The nature of crystal formation depends on the state of the cell membranes, the concentration of substances dissolved in the cells, the degree of hydration of proteins and other properties of the product. Among the factors affecting crystal formation, scientists recognize that the speed of freezing is the most important [8]. The higher the freezing speed, the less damage to the muscle tissue structure and the higher the quality of the frozen product [9].

Works [10–14] proved that acceleration of the freezing process can be achieved by reducing the thickness of the product, lowering the temperature of the cooling medium, and increasing the coefficient of heat transfer from the product to the medium.

During slow tissue freezing, crystallization centers are formed earlier in the intercellular space, since the intercellular fluid has a slightly lower concentration, which means that the value of the cryoscopic point is higher than the intracellular one. But as soon as they are formed, the concentration of intercellular fluid and its osmotic pressure increase, water diffuses from the cell into the intercellular space. At the same time, large crystals are formed in the intercellular substance, which press on the cells, causing stretching and partial destruction of their structures [11].

According to [12], rapid freezing of meat leads to the formation of ice crystals not only in intercellular spaces, but also in cells. The speed of their formation is higher than the speed of movement of moisture, so a significant part of the liquid turns out to be frozen where it was before freezing. With this method of freezing, small ice crystals are formed, which are evenly distributed in the cells and intercellular space. In this case, the nature of the distribution of frozen water is little different from the nature of its distribution in fresh meat, and almost no histological changes are observed in the muscle tissue.

The formation of large ice crystals in the practice of freezing meat is an undesirable phenomenon. During freezing, the volume of water increases by 10%. In the case of the formation of large crystals and an increase in volume, the intercellular space expands and the connective tissue layers are destroyed by the sharp edges of the crystals, the tissue loosens, the muscle fibers are deformed and sometimes destroyed. Freezing, thus, is accompanied by significant tissue changes. The size and nature of the distribution of crystals in tissues and the related degree of destruction of morphological structural elements determine the size of tissue fluid (meat juice) losses during defrosting of meat and its subsequent mechanical processing (demolition, veining).

Works [11– 13] proved that the degree of decrease in the hydrophilicity of proteins depends on the speed of meat freezing, the depth of autolysis of meat before freezing, the conditions and duration of meat storage. The maximum native properties of meat proteins are preserved under the condition of rapid freezing of steamed meat. The greatest destruction of the morphological structure occurs in the case of freezing of meat in a state of complete postmortem conjuration.

Many researchers associate damage to the native structure of proteins during freezing with the effect of concentrated salt solutions. At the same time, both the direct influence of electrolytes through the neutralization of protein functional groups, the modification of ion dipole interactions between polar amino acid residues, and the disruption of the stabilization layer of dipoles around the macromolecule are possible [51].

During freezing, mechanical damage to protein chains is possible due to the stresses that arise in the tissues in the event of the formation and growth of crystals exceeding the energy of the covalent bond.

The process of aggregation of myofibrillar proteins, which is accompanied by the formation of insoluble complexes, leads to a decrease in the hydrophilic properties of meat, a decrease in moisture-binding capacity and an increase in stiffness, and increases the resistance of proteins to the action of proteolytic enzymes [56].

Thus, the creation of new types of frozen combined chopped products requires careful substantiation of the moisture-retaining properties of the functional additive to chopped masses, including the study of the behavior of combined minced meat during and after freezing.

Objective of the article — theoretical substantiation and experimental determination of optimal technological parameters of functional meat and fish chopped semi-finished products.

Presentation of the main study material. Chopped culinary products are heterogeneous systems in which moisture has different forms of connection with dry matter. The state of moisture in such products is influenced by many factors: the nature and amount of ingredients in the recipe; methods of mechanical preliminary processing; mass ratios of ingredients; food additives and spices, etc. Information on the behavior, structure, and properties of bound moisture in a wet product is the starting point for analyzing its behavior during storage as a semi-finished product and heat treatment. It is known [14] that the amount and structure of bound moisture depend on the intensity of heat and mass transfer processes during thermal action, which in turn is determined by the initial characteristics of the humidity of the object being studied. Moisture determines the juiciness of the finished chopped product, the consistency, and the output of the finished product. Therefore, for the scientific justification of the technologies being developed, it is necessary to study the influence of technological methods on the ratio of different types of moisture.

When studying the behavior of moisture by known methods in high-moisture ground meats of chopped products, some difficulties arise. Thus, the tensometric method is quite long and cannot be applied to objects outside the hygroscopic state of wet material. Disadvantages of radio spectroscopic methods, such as NMR, are difficulties in identifying different forms of moisture in high-moisture material, so it is required to use additional methods that separate the contained water into free and bound, for example, drying or freezing. These techniques are additional factors that complicate the measurement technique and irritate the sample itself. In addition, the results obtained by such methods of indirect analysis do not always satisfactorily correlate with the thermodynamic characteristics of the object. Therefore, a method was chosen that allows you to examine samples with different moisture content and different consistency.

Meat and fish model chopped masses, two- and three-time grinding, containing 20%, 25% and 30% Jerusalem artichoke additives (to the mass of the main raw material) were selected for research. The range of variation in the content of the additive is chosen based on the preliminary organoleptic evaluation of semi-finished products and finished products. In fig. 1 presents examples of averaged thermograms for the studied samples.

To facilitate the analysis of the shape of the curves, they are given on a relative scale, which was obtained by normalizing the current values of the signal intensity to the maximum intensity and the current moment of time to the total cooling duration of the given sample.

First of all, it should be noted the high sensitivity of the applied method to the condition of the samples: the figures clearly show that depending on the sample preparation technology, the shape of the curve (local extremes, inflections, slopes) changes its appearance, amplitude and position along the coordinate axes.

It should be noted that a general or characteristic tendency for chopped meat and fish products is that the increase in the grinding rate from two to three times is fixed by the effect of «convergence» of the cooling curves of the samples. This can be explained by the fact that the shape of the curve itself depends on many factors and, in particular, on the thermophysical characteristics of the sample under study, namely on thermal conductivity. It is thermal conductivity that determines the rate of deepening of the water crystallization zone under the same conditions for heat exchange with the coolant. Since it is obvious that the samples become more homogeneous in their structure during three-fold grinding, the differential thermocouple evidence curves also converge.

As water crystallization begins in the so-called crystallization centers (usually inhomogeneities), the concentration of substances dissolved in water changes (the concentration increases, which shifts the eutectic point toward low temperatures). In addition, the destruction (lysis) of cells occurs, due not so much to the mechanical effect of growing ice crystals, but to a change in the strength of the cell envelope (membrane). Of course, cells of animal origin have a more complex structure and contain less water than cells of plant tissues. Therefore, here and further we will only discuss the observed thermal effects (areas under the curves shown in Fig. 1).

It should be noted that the spread in the shapes and amplitudes of the curves themselves is smaller for chopped fish products, which is due, obviously, to a smaller effect of the additive on the structural and mechanical characteristics of the studied semi-finished products.

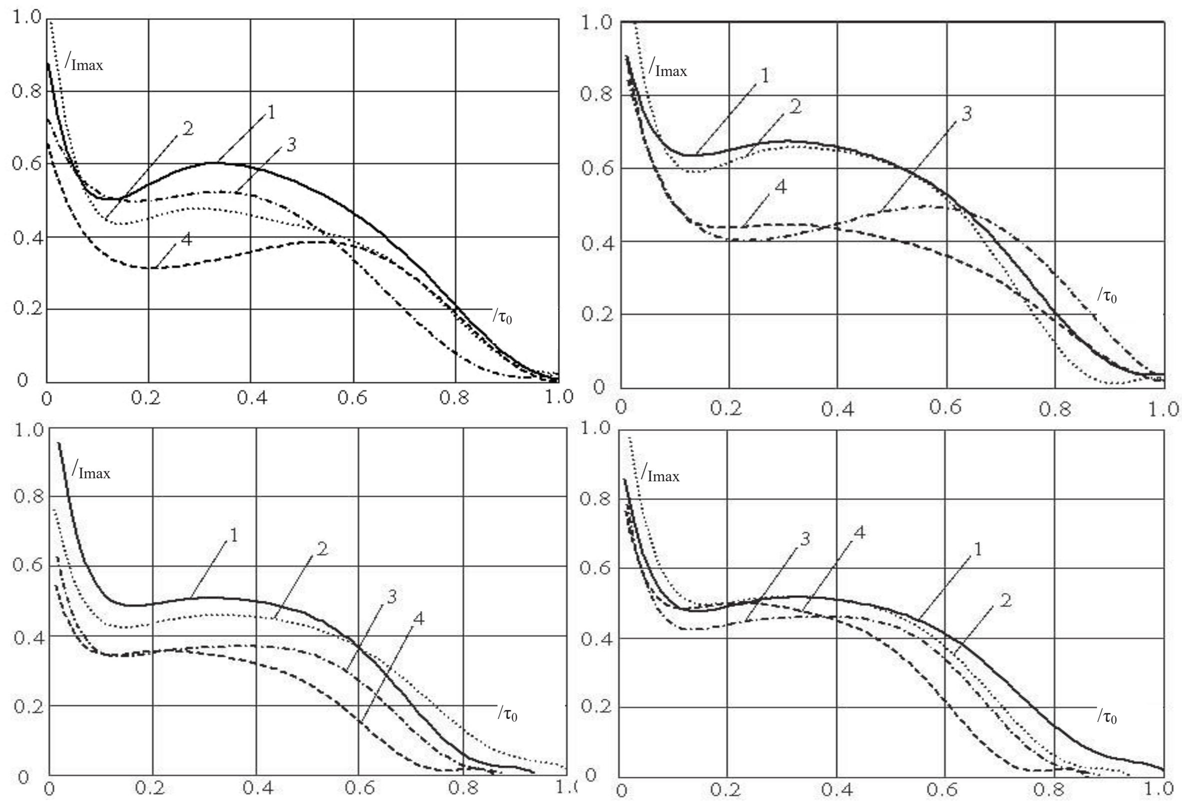

Figure 1 — Averaged thermograms of model meat (А, Б) and fish (В, Г) chopped masses with two-fold (А, Б) and three-fold (В, Г) mincing: (1 — control; 2 — samples with a 20% supplement; 3 — samples with a 30% supplement; 4 — samples with a 25% supplement)

There is also a peculiarity in the position of local maxima for curved meat and fish cut products. This is especially visible on the temperature curves for meat semi-finished products. Depending on the amount of plant additive, this maximum shifts to the right at 25% and reverses (shifts to the left) at 30%. The presence of a maximum on the curve indicates the arrival of the moment of time when the rate of water crystallization is maximum, that is, the heat release is maximum. At the same time, the temperature of the sample itself is lower than 0 ºC, that is, the starting point of water crystallization shifts. This means that in this case the mass content of the plant additive plays a major role in the crystallization process. Most likely, this amount of additive in the minced meat "compensates" for heterogeneity in the thermophysical characteristics of the ingredients of the semi-finished product and the sample behaves as a whole. It is impossible to confirm with great accuracy, but the observed fact indicates a possible rational amount of plant additive as a binding substance, which ensures greater homogeneity of the chopped product.

The main results of this study are shown in fig. 2. The presented data were interpreted as follows. The area under the curve of the differential thermocouple for the studied samples was related to the corresponding area of the control ones and was multiplied by 100%. Thus, we obtained an estimate of the amount of frozen water in relation to the control.

As can be seen from Figure 2, for all tested samples, regardless of the type of chopped products and the frequency of grinding, the amount of frozen water is less than for the control. This indicates the effect of the plant functional additive on the ratio between frozen (free) and non-frozen (bound) water. At the same time, it should be noted that this indicator to a certain extent

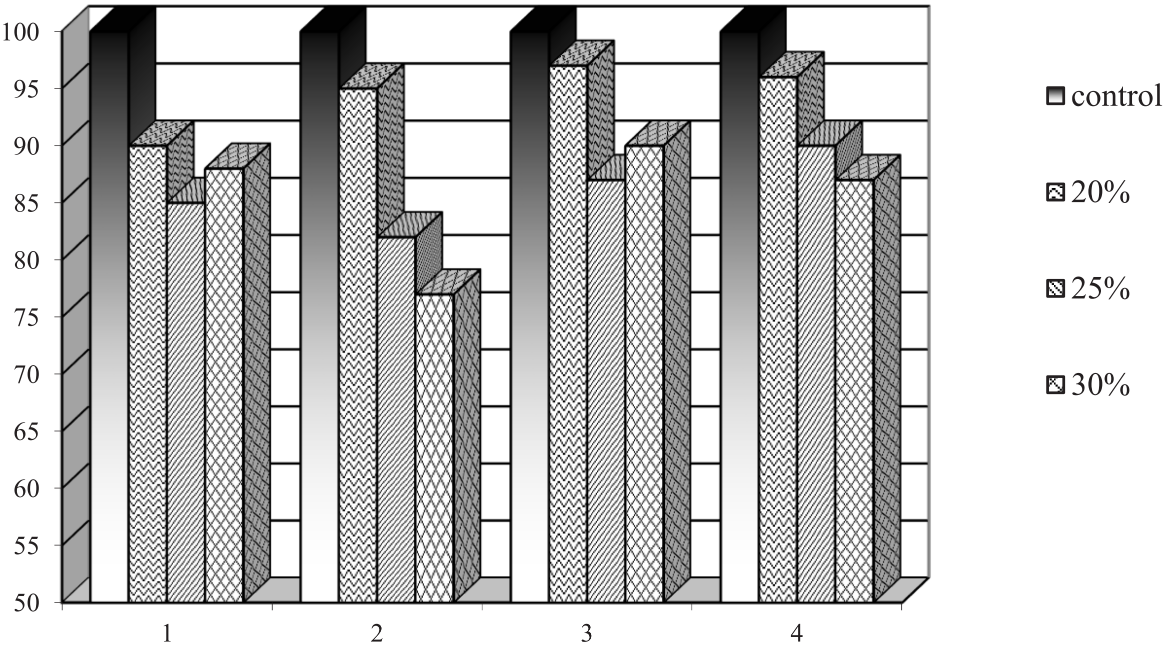

Figure 2 — Amount of frozen water in chopped products with different content of functional additive relative to control samples: (1 — minced meat, 2-fold grinding; 2 — minced meat, 3-fold grinding; 3 — minced fish, 2-fold grinding; 4 — minced fish, 3-fold grinding)

has some convention in relation to the commonly used ideas about free and bound water. This is explained by the fact that the tissue structure of raw materials of animal and plant origin is somewhat different, and, first of all, due to the difference in cellular structure and intracellular chemical composition.

The results show that the introduction of the additive helps to increase the proportion of unfrozen moisture. The fact that with three-fold grinding there is no minimum in relation to the amount of additive (observed at 25%), indicates the complex effect of both additives and mechanical processing of products.

Based on this, it is possible to predict the existence of rational technological methods for obtaining the effect of increasing the moisture-retaining capacity of the studied model samples, namely: determining the optimal amount of plant additives and the frequency of grinding. According to the obtained results, it can be seen that with double grinding and a 25% additive in both meat and fish products, there is a minimum amount of frozen moisture, that is, the maximum moisture-retaining capacity of semi-finished products should be expected. There is no such minimum when grinding three times. The reason for this may be the factors outlined above, namely, the shift of the moisture crystallization point towards low temperatures and the increase in homogeneity in the minced meat structure. Therefore, in order to choose a rational value of the mass additive (higher than 25%) during three-time grinding, it is necessary to be guided, first of all, by the organoleptic indicators of the finished product and the rationality of using one more stage of mechanical processing of raw materials.

To confirm the correctness of the conclusions, the following analysis can be performed. As you know, any moist material is characterized by two states in relation to the environment at a given temperature: moist, which is non-equilibrium, and in this state the moisture evaporates, and hygroscopic — equilibrium, at a given value of air humidity, the material has the so-called equilibrium moisture content . It is in the area of the hygroscopic state that the energy of moisture connection with the material is determined. The extreme point of the hygroscopic state is determined at a relative air humidity equal to 100% and for most types of raw materials containing protein, it is difficult to determine due to the deterioration of the product before the equilibrium occurs. But for most food products, this extreme point is characterized by an equilibrium moisture content in the range of 35% to 60%. At the same time, moisture content (but not moisture content) is defined as the ratio of the mass of water in the product to the mass of the dry residue. According to the results obtained above, it was found that the amount of unfrozen water in 100 g of minced meat varies from 17 g (for control) to 22 g (for 30% additive and triple grinding), which in terms of the initial moisture content of these samples gives the value estimated equilibrium moisture content at 100% air humidity — 45...50%. For fish products, the amount of unfrozen water in 100 g of products varies from 15 g (for control) to 18 g (for 30% addition and triple grinding), and similar calculations give the value of the equilibrium moisture content of 40...45%. This fully correlates with the hygroscopic area of moisture content for these types of food products.

Conclusions. Thus, it was found that the functional plant additive to minced meat and fish products helps to increase the share of unfrozen moisture at temperatures up to -18 C. With two-fold mincing, the rational value of the additive should be considered 25%, and with three-fold mincing — up to 30%. In the latter case, the factor limiting the introduction of the additive is the organoleptic indicators of the finished products while maintaining the high moisture-retaining capacity of the semi-finished product.

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***Мета** — теоретичне обґрунтування і експериментальне визначення оптимальних технологічних параметрів функціональних м'ясних і рибних посічених напівфабрикатів.*

***Методи**. Для досліджень були обрані м'ясні та рибні посічені вироби, дво- та триразового подрібнення, що містять 20%, 25% та 30% функціональної добавки. Діапазон варіювання вмістом добавки обраний з міркувань попередньої органолептичної оцінки напівфабрикатів та готових виробів. Кожен експеримент проводився з триразовою повторністю, а похибка вимірювань величин, що реєструються (різниці температур) становила 5%, що забезпечено високоточним потенціометром EZ-9. При розрахунках кількості вологи точність вимірювань маси вологи у зразку в абсолютних одиницях була ±0,5°10 $^{-3}$ кг. Маса досліджуваних зразків становила від 20 до 25 г, що забезпечувало достатню чутливість в експерименті стосовно процесу кристалізації водної фази виробів. Температура в термостаті (навколишньому середовищі) підтримувалася постійною -18°С. Записані безперервним автоматичним потенціометром лінії оцифровувалися за допомогою програмного засобу Grafula 3, а потім у середовищі Mathcad апроксимувалися поліноміальною функцією 5-го ступеня. Апроксимуючу функцію диференціювали для визначення точок перегину на кривій і визначення меж інтегрування при знаходженні площі під ділянкою кривої, що відповідає замерзанню води в зразку. Методика заснована на низькотемпературному калориметричному методі вимірювання кількості теплоти, що виділяється при заморожуванні вільної вологи у харчовій сировині.*

***Результати**. Досліджено теплофізичні властивості модельних посічених мас на основі м'яса та риби з функціональною добавкою. Визначено вплив кратності подрібнення і концентрації добавки на співвідношення між вимороженою (вільною) і не вимороженою (зв'язаною) водою. Визначено оптимальні технологічні параметри виробництва напівфабрикатів. Встановлено, що функціональна рослинна добавка у фарш посічених м'ясних і рибних виробів сприяє збільшенню частки невимороженої вологи при температурі до –18°С. При двократному подрібненні раціональною величиною добавки слід вважати 25%, а при трикратному подрібненні — до 30%. У останньому випадку чинником, лімітуючим внесення добавки, є органолептичні показники готових виробів при збереженні високої вологоутримуючої здатності напівфабрикату.*

***Ключові слова**: модельні посічені маси, фунціональна рослинна добавка, теплофізичні властивості, виморожена волога, технологічні параметри.*