

Досліджено вплив параметрів (температури та тривалості) пасерування борошна пшеничного на його водопоглинальну здатність під час гідротермічної обробки. Встановлено, що нагрівання зразків борошна пшеничного пасерованого в інтервалі температур 80...90 °C сприяє прискоренню водопоглинальної здатності. Зразки борошна пшеничного пасеровані за температури 110...120 °C досягли максимальних показників водопоглинальної здатності за 10...20 хв. Результати досліджень є важливими для забезпечення можливості регулювання ступеню набухання пасерованого борошна в технології крокетної маси.

Досліджено в'язкість зразків модельних систем борошна пшеничного залежно від температури та тривалості пасерування. Встановлено, що в'язкість модельних систем знижується з підвищенням температури та тривалості пасерування борошна пшеничного у порівнянні з нативним. Разом з тим, показник відносного коефіцієнту стійкості модельних систем збільшується в межах 0,91...0,98. Визначено раціональну зону в'язкості зразків модельних систем борошна пшеничного пасерованого. Доведено доцільність використання в технології крокетної маси для кулінарної продукції здатності компонентів борошна пшеничного пасерованого до утворення зв'язаної пластичної маси під час гідротермічної обробки.

Встановлено вплив температури та тривалості пасерування на насиченість кольору зразків модельних систем борошна пшеничного пасерованого. Встановлено, що пасерування борошна пшеничного з жировим компонентом істотно не впливає на колір, але змінює його насиченість. Важливо, що за визначених технологічних чинників колір зразків модельних систем характеризується достатньою стабільністю і є характерним технологічним показником системи крокетної маси.

Результати досліджень надали змогу для регулювання та коригування структурно-механічних характеристик крокетної маси на основі борошна пшеничного

Ключові слова: борошно пшеничне пасероване, параметри пасерування, гідротермічна обробка, властивості борошна, водопоглинальна здатність, крокетна маса

STUDYING THE INFLUENCE OF HYDROTHERMAL TREATMENT PARAMETERS ON THE PROPERTIES OF WHEAT FLOUR IN THE TECHNOLOGY OF A CROQUETTE MASS

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1. Introduction

Under conditions of growing competition in the global and national consumer markets, innovations are the source of comprehensive development for enterprises in food industry and restaurant business, the driver for strengthening their market positions. The key tasks that are solved by implementing the innovations include the rational utilization of raw materials, as well as making products with improved consumer properties based on new production techniques.

Given the wide variety of culinary products, croquettes (French, *croquer*) are widely spread at restaurant establishments of different formats. Their multifunctional technological purpose, as a main course or a side dish, high nutritional properties, a possibility to create a wide range of products where they serve as the base, contribute to the development of industrial technologies for their production.

Technological characteristics of the mass for croquettes are determined by its composition (a type of raw materials),

the properties of formulation components (humidity, water-absorbing capacity of substances that make up components, the strength of bond between the disperse particles), as well as by the treatment parameters (the degree of grinding, a type of heat treatment) [1-3].

The use of vegetable raw materials in the production technology of croquettes has certain disadvantages related to their seasonality, unstable quality indicators during storage, the need for a number of technological operations when preparing a given type of raw materials. The specified shortcomings complicate the technological production process, resulting in the products whose quality indicators are unpredictable.

Traditional technologies for making croquettes are characterized by the presence of structure-forming agents – wheat flour, starch-containing cereals, wheat bread, whose components' technological properties define consumer characteristics of the finished product [1]. One of the best structure-forming agents for the systems of croquette masses in

terms of technology is the wheat flour, which is characterized by the capability to form structured systems, by the neutrality of taste and aroma, which provides variability of the formulation composition in finished products. This is the reason why the use of sautéed wheat flour in the technology of a croquette mass would make it possible to obtain a universal product; on the one hand, varied in assortment and consumer properties, on the other hand, it would enable the mechanization of the production process in order to reduce the number of technological operations.

Given the expediency of using the sautéed wheat flour in order to produce a croquette mass, it is a relevant task to study the influence of parameters of hydrothermal treatment on the technological properties of wheat flour.

2. Literature review and problem statement

A review of information sources allows us to assert that in the technology of flour-based culinary, pastry, and bakery products the technological properties of wheat flour are crucial in forming the quality indicators of finished products. They are purposefully regulated by being exposed to the influence of such technological factors as the parameters of dry heat treatment [6], steaming [7, 8], the temperature of dough, the temperature and duration of dough formation [1], formulation components, etc. [9–11].

Paper [4] estimated the influence of flour particles size, the process of autoclaving, on the thermomechanical properties of dough and quality characteristics of the finished product. Results of the study showed that reducing the size of particles in the thermally untreated flour reduced hardness of the products and increased the volume of bread [5]. Heat treatment could be a technological stage when obtaining a product without changing its consumer properties. Researchers focused on the influence of heat treatment of flour wheat (dry and hydro) on its properties. It was shown that the hydrothermally treated samples of flour had a greater viscosity in suspension and demonstrated the improved rheological properties of dough [7]. Proteins in flour partially undergo denaturation, gliadin and glutenin almost do not change quantitatively, whereas the content of water-soluble proteins reduces, and there is a simultaneous starch gelatinization. The elevated level of moisture content contributed to the modification of both the structure of protein and the rheological characteristics of dough. A given research considered the properties of native wheat flour. However, the issue of the impact from the preliminary sautéing of flour on its technological properties was not examined at all.

The authors of [6] confirmed a hypothesis on that the thermal treatment facilitates the swelling of starch granules at elevated temperature. In addition, the research results demonstrated the improved capability of the thermally treated flour to swell. The protein denaturation was marked by the lack of formation of the gluten frame after heat treatment. Research results [8] showed that even after being thermally treated, the gluten retained moisture. However, left unresolved was the issue of the impact of additional formulation components on the technological properties of sautéed wheat flour.

Paper [9] noted that an increase in the content of rice flour, mixed with wheat flour, led to a decrease in the indicators of water-absorbing capacity. However, the paper failed to address the issue about the dependence of water absorption for wheat flour and the viscosity of water-flour

suspensions. A variant of solving this task was a research into viscosity of water-flour suspensions at hydrothermal treatment. Such an approach was employed in paper [10] that reported a study into the influence of polysaccharides on the functional properties of wheat flour. It was established that adding them improves the water-absorbing capacity and viscosity of flour suspensions, with an increase in the stability of starch gel.

The results of study [11] are important in terms of the influence of triglycerides on the rheological properties of starch. It is shown that adding them to starch suspensions impacted the gelatinization, the rheological behavior and stabilization when heated, as well the changes in the distribution of water during heat treatment. When adsorbed at the surface of starch grains, fat shields part of the hydrophilic groups, preventing their interaction with water and the formation of paste. However, results of the research mostly considered the technological properties of starch, while the issue of the impact of fat on the properties of wheat flour were not considered at all.

Systematization and analysis of the scientific literature allow us to affirm that in the course of the hydrothermal treatment of sautéed flour its main components undergo the following changes: proteins are partly exposed to denaturation, starch is gelatinized. The presence of fat in water-flour suspensions inhibits the interaction between starch grains and wheat protein micelles and water, as well as the formation of a strong gel, with an increase in plasticity. However, confirming this hypothesis lacks data on the water-absorbing capacity of sautéed flour, viscosity, and the color of systems based on it.

An analysis of the formulation composition and the technological process of croquettes production has revealed that the implementation of conventional (traditional) technologies that imply the application of a vegetable (mostly potato-based) mass as the structural base [1–3] does not make it possible to attain significant competitive advantages. An important drawback in existing technologies of croquettes is also the high labor-intensity of the technological process, the low level of its mechanization, reliance on the technological properties of basic raw materials.

We have substantiated analytically the expediency of using, as a structure-forming agent in the croquette technology, the sautéed wheat flour, the implementation of whose technological properties would make it possible to obtain products with stable indicators of quality and safety in the technological flow of their production.

At the same time, the above-cited scientific and practical basis for the implementation of technological properties of wheat flour in a combination with its chemical composition [4], the influence of technological factors [5–7] on the properties of dough and quality characteristics of the finished product, is mainly related to the production of flour-based culinary and confectionery products.

Thus, there is reason to believe that the lack of certainty about the influence of hydrothermal treatment parameters on the technological properties of sautéed wheat flour in the technology of a croquette mass necessitates undertaking a research into this issue.

3. The aim and objectives of the study

The aim of this study is to determine the influence of parameters of the hydrothermal treatment of flour wheat on

its technological properties in the production of a croquette mass. This would make it possible to influence the process of the sautéed flour gelatinization and to change the viscosity of systems that are based on it, in order to ensure the pre-defined forming capability and consumer properties of the finished product.

To accomplish the aim, the following tasks have been set:

- to explore the impact of sautéing the wheat flour on the dynamics of water absorption;
- to determine the effect of technological parameters on the viscosity of model systems of sautéed wheat flour;
- to establish the influence of technological parameters on the color of model systems of sautéed wheat flour.

4. Materials and methods to study the properties of a croquette mass

Research materials:

- wheat flour, high grade, in line with GSTU 46.004-99;
- sautéed wheat flour (preliminary thermally-treated at temperatures 100.0 ± 1.0 °C, 110.0 ± 1.0 °C, 120.0 ± 1.0 °C);
- a fat component (ratio 1:2) – refined sunflower deodorized oil, in line with DSTU 4492:2005, and cream-based butter, 72.5 %, in line with DSTU 4399:2005;
- model systems “wheat flour – drinking water” (1:4.8), “sautéed wheat flour – fat component – drinking water (1:0.8:4.7), “sautéed wheat flour – fat component – drinking water” (1:0.8:4.7), hydrothermally-treated at different parameters.

The main indicators for the technological properties of samples of sautéed wheat flour, which were determined in the course of our experiment, are as follows: water-absorbing capacity (N , %), viscosity (η_{\max} , AU), light reflection spectrum (E).

The water-absorbing capacity of the samples of native flour wheat and sautéed wheat flour at a temperature of 100, 110, 120 °C, at the temperature of water environment 70...90 °C, was determined using a weight method [12, 13].

We determined the viscosity of model systems “sautéed wheat flour – fat component – drinking water” at a constant increase in temperature at the Brabender amylograph (Brabender® GmbH & Co.KG, Germany) [12]. The starting temperature of model systems was 25.0 ± 0.1 °C, an increase in the heating temperature was 1.5 ± 0.1 °C per minute. The research results were displayed on the recorder tape in the form of curves. Viscosity of the systems was determined in conditional units at the amylograph, ranging from 0 to 1,000. The relative resistance coefficient of model systems was examined and computed in line with procedure [10].

The light reflection spectrum from the examples of model systems “sautéed wheat flour – fat component – drinking water” was determined at the device “Spekol” (Carl Zeiss Jena, Germany) [14]. The examined samples were placed in a cuvette of the device through which we passed light of a certain wavelength ranging from 420 to 540 nm. For each wavelength, we recorded the degree of light reflection by a sample.

Statistical processing of research results, as well as construction of graphs and charts, employed the software packages Statistika and MS Office Excel.

5. Results of influence of the technological factors on parameters of the flour wheat hydrothermal treatment in the technology of a croquette mass

A croquette mass based on flour wheat is a semi-finished product obtained as a result of hydrothermal treatment of sautéed wheat flour, with further adding the taste-aromatic components and a filler; it is used for making molded culinary products, deep fried.

It is known that technological properties of flour wheat are defined not only by the protein-proteinase complex, but also by the state of the carbohydrate-amylase complex. This factor is important for forming the rheological characteristics of systems based on wheat flour. The sautéing temperature of wheat flour is in the interval of 100...120 °C [1]. It is also known [15, 16, 17] that the gelatinization temperature of starch grains characterizes the process of gelatinization and is essentially a spontaneous rupture of the outer shell of the grain as a result of the increased pressure inside a grain. That is, gelatinization must be associated with mechanical phenomena.

5.1. Studying the influence of wheat flour sautéing parameters on the dynamics of water absorption

Interaction between water and dry substances in food products is of fundamental importance in terms of both the organization of a technological process and ensuring the quality of finished culinary products. We investigated the behavior of starch in flour wheat as a structure-forming component of the system in a water medium by examining the water-absorbing capacity coefficient. In this case, the mass and volume of the examined sample change, and the system enters the jello state. The amount of water, which can be absorbed by flour, relates to its chemical composition, the content of polymers, the state and size of the moisture-absorbing surface area. Note that these characteristics of flour depend on parameters of its hydrothermal treatment.

Results for the water-absorbing capacity of samples (N , %), depending on the temperature of their sautéing, at an increase in the medium temperature within 70...90 °C, are shown in Fig. 1.

It should be noted that the process of flour water-absorbing capacity proceeds in line with a certain pattern, predetermined by different temperature regimes of both a water medium and the pre-treatment of the examined object. Increasing the sautéing temperature of wheat flour samples contributes to a decrease in the values for water-absorbing capacity (Fig. 1). The samples attain maximal water-absorbing capacity at a water medium temperature of 70 °C over 25...30 min. (Fig. 1, *a*), at 80 °C – over 15...20 min. (Fig. 1, *b*), at 90 °C – over 10...15 min. (Fig. 1, *c*).

As one can see, at a water medium temperature of 70 °C the samples of wheat flour are partially susceptible to water-absorption (Fig. 1, *a*): sautéed at 120 °C to 63 %, at 110 °C – 72 %, at 100 °C – 78 %, native – 88 %. In this case, there is no any increase in viscosity. Note that the further heating of the water medium in the temperature range 80...90 °C (Fig. 1, *b*, *c*) contributes to the acceleration of the flour water-absorbing capacity. Indicators for water-absorbing capacity at a water medium temperature of 80 °C (Fig. 1, *b*) decrease for the samples of sautéed wheat flour at 100 °C by 1.6, at 110 °C by 1.85, at 120 °C by 2.14 times, compared to native. Data in Fig. 1, *c* indicate a decrease in values for wa-

ter-absorbing capacity of sautéed flour at 100 °C by 2.5, at 110 °C by 2.6, at 120 °C by 2.83 times, compared to native.

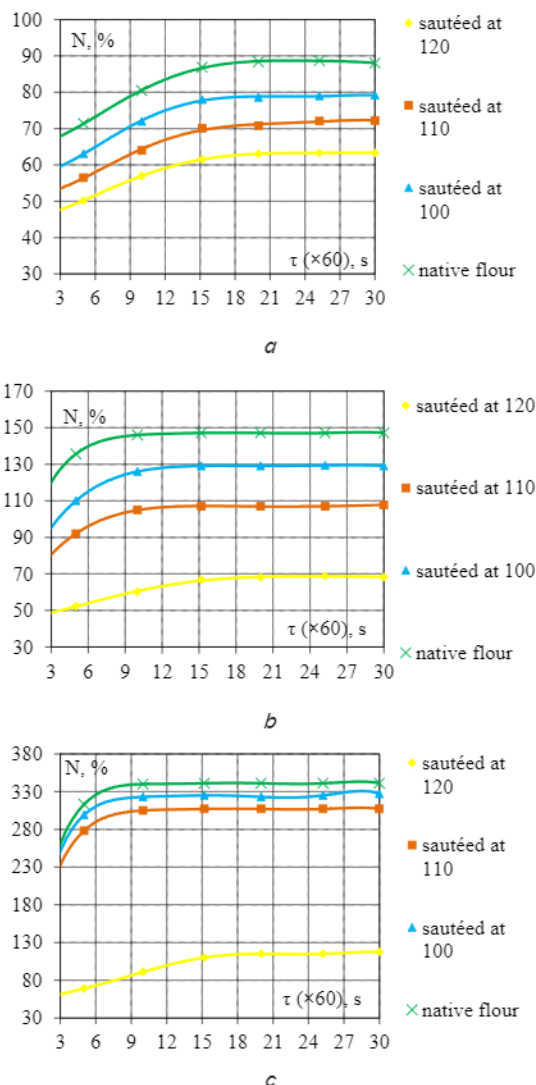


Fig. 1. Water-absorbing capacity of wheat flour depending on the sautéing temperature: *a* – 70 °C, *b* – 80 °C, *c* – 90 °C

5. 2. Studying the influence of technological factors on viscosity and stability of the model flour systems

In the technology of a croquette mass, we used as a fat component a mixture of the refined deodorized sunflower oil and cream-based butter, 72.5 %, ratio 1:2. Under these conditions, fat forms stable complexes with the molecules of protein and starch polysaccharides. An important role in this process belongs to the triacylglycerols of saturated and unsaturated fatty acids. When adsorbed at the surface of starch grains and wheat protein’s micelles, fat shields part of hydrophilic groups, preventing their interaction with water and the formation of a strong gel. By weakening the bond between protein’s micelles, as well as the polysaccharides of starch in wheat flour, fat improves the plasticity of a

model system. That will ensure the desired structural- mechanical properties for a croquette mass.

Based on the results of theoretical and analytical studies, it is expedient to sauté wheat flour in the presence of a fat component in ratio 1:0.8 at a temperature of 110...120 °C, which would contribute to the fast and uniform warming of flour (owing to the high heat conductivity of fat) and to improving a food value of the finished product [11, 15, 18, 19].

The results of data acquisition about the process of water-absorption and gelatinization of samples of the model systems “sautéed wheat flour – fat component – drinking water” are given in Table 1.

It should be noted that a change in viscosity is one of the important technological characteristics for the systems of a croquette mass based on sautéed wheat flour, which defines the parameters for technological process of production.

Based on results from Table 1, one can say that increasing the sautéing temperature of samples leads to an increase in their viscosity, which is associated with the water-absorbing capacity of starch grains [15, 20, 21].

Maximum viscosity (Table 1) is the largest for the samples sautéed at a temperature of 100 °C over 10 min. – 940 AU, and at 120 °C over 5 min. – 920 AU. As one can see, the indicator of maximal viscosity of samples reduces with a further rise in temperature and duration of sautéing.

As one can see (Table 1), the magnitude η_{min} that approaches the magnitude η_{max} testifies to the increased stability of the systems’ structure. A relative coefficient of the model systems’ stability grows with the increased temperature and duration of heat treatment – over 5, 10, 15 minutes at 110 °C and 120 °C within 0.91...0.98 compared to native flour (0.88).

Results of studying the viscosity and textural properties of the model systems depending on the sautéing temperature and duration are shown in Fig. 2.

Fig. 2 shows that the rational region of viscosity is within the range for the samples of model systems, sautéed over 10 min. at a temperature of 110 °C and over 5 min. at a temperature of 120 °C. That corresponds to the region in which the samples attain soft textural properties.

Table 1

Influence of the wheat flour sautéing parameters on the process of gelatinization and on the activity of amylolytic enzymes in flour

No. of entry	Sautéing temperature, °C	Sautéing duration, min.	Gelatinization starting temperature, t_s , °C	Gelatinization final temperature, t_f , °C	Maximal viscosity, η_{max} , AU	Viscosity η_{min} at 95 °C, AU	Gelatinization velocity, v , AU/min
1	native	native	68.5	94.0	500	490	29.4
2	100	5	64.0	94.7	780	720	38.0
3		10	59.5	88.7	940	840	48.2
4		15	61.0	91.0	870	770	43.5
5		5	55.0	85.0	920	860	46.0
6	120	10	59.5	88.0	800	730	42.1
7		15	61.0	89.5	690	620	36.3
8	140	5	52.0	82.0	700	660	35.0
9		10	58.0	91.0	620	620	28.1
10*		15	–	–	–	–	–

Note: * – the sample was not examined because it acquired a sharp burnt smell following the sautéing under given conditions

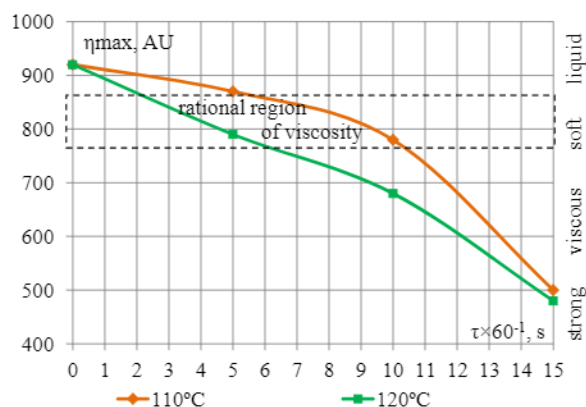


Fig. 2. Viscous and textural properties of the model systems “sautéed wheat flour – fat component – drinking water” depending on the sautéing temperature and duration

5.3. Studying the influence of technological parameters on color of the model flour systems

One of the important technological indicators for a croquette mass based on wheat flour is its color. Therefore, we think it appropriate to investigate a light reflection spectrum for the samples of flour wheat depending on the sautéing temperature. Special emphasis when examining the spectrum shown in Fig. 3 should be given to a frequency range of 450...500 nm, over which the sautéed samples are visually characterized by a yellow tint. Data from Fig. 3 show that sautéing at 110 °C and 120 °C has almost no effect on a change in the color, though it changes its saturation in a range of 450...500 nm.

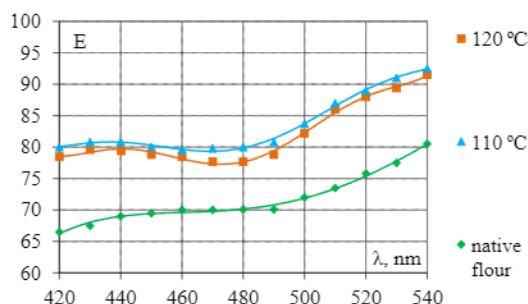


Fig. 3. Light reflection spectrum for the samples “sautéed wheat flour – fat component – drinking water” depending on the sautéing temperature

Based on the results of our study, we have determined parameters for the heat treatment of wheat flour for the production of a croquette mass.

6. Discussion of results of studying the influence of hydrothermal treatment parameters on the properties of wheat flour in the technology of a croquette mass

When determining the water-absorbing capacity of sautéed wheat flour depending on the temperature of sautéing, which is derived from data in Fig. 1, one can see that an increase in the temperature of sautéing contributes to a decrease in the values for water-absorbing capacity. This is predetermined by the destruction of wheat flour proteins during sautéing. Such a mechanism of the effect of sautéing

temperature must be a factor to control the process of water-absorbing capacity of flour, due to which maximal values are observed when sautéing the samples at a temperature of 110...120 °C over 10...20 min. The data indicate minor destruction in the structure of samples of model systems that underwent sautéing. This is probably explained by the starch dextrinization and protein denaturation during sautéing.

Of particular interest is the interpretation of results of the influence exerted by the sample sautéing parameters on viscosity of the systems, given in Table 1. That confirms establishment of the fact of a decrease in viscosity with an increase in temperature and duration of flour sautéing to 17 % in comparison with native. This does not disagree with practical data known from papers [6, 8]. Their authors also attributed a decrease in viscosity to the loss of water-absorbing capacity by the proteins of gluten in thermally-treated flour and their impossibility to form a sticky mass.

In order to prove this argument, it will suffice to carefully investigate the viscosity and textural properties of the model systems “sautéed wheat flour – fat component – drinking water”. Comparing data on viscosity with the textural properties of the systems indicates the attainment of the desired characteristics by the sautéed samples over 10 min at a temperature of 110 °C and over 5 min. at a temperature of 120 °C.

Of interest are the results of studying the color of the sautéed flour systems that indicate that the sautéing has almost no effect on a change in color, although it changes its saturation in the range of 450...500 nm.

However, in contrast to the research results reported in [5–7], the acquired data on the influence of flour sautéing parameters on the rheological characteristic of samples during hydrothermal treatment allow us to assert the following:

- application of the hydrothermal treatment would extend the possibilities for obtain products from a croquette mass with the predefined consumer properties and a shape-forming capability;
- the temperature and duration of flour sautéing exerts a significant influence on the technological properties of wheat flour.

Such conclusions could be considered appropriate from a practical point of view, as they make it possible to reasonably approach the manufacture of products from a croquette mass. From a theoretical point of view, they allow us to argue about defining the mechanism of water-absorption processes and of changes in the flour viscosity depending on the sautéing parameters; this constitutes the merits of this research.

However, one should note that the results from determining viscosity (Table 1 and Fig. 2) indicate the ambiguous impact of temperature and duration of sautéing on the textural properties of model systems. This manifests itself in the first place by the unresolved issues regarding the study into structural-mechanical indicators and shape-stability of the croquette mass. Such an uncertainty imposes certain restrictions on the implementation of results obtained, which could be interpreted as the shortcomings of present study. The impossibility to eliminate the specified limitations within the framework of this study could lead to a potentially interesting field in the further research. It could focus on determining the factors of influence on the maximal shear stress of the croquette mass, its shape-stability and adhesion. If identified, it would make it possible to explore an oppor-

tunity to control the structural-mechanical properties of croquette mass and to determine those technological factors that could regulate them.

7. Conclusions

1. Our research has established that the maximal indicators for water-absorbing capacity characterize the samples of wheat flour sautéed at a temperature of 110...120 °C over 5...10 min. Given this, it can be argued that the temperature and duration of sautéing significantly affect the change in proteins and starch in wheat flour.

2. It was determined that the indicator of maximal viscosity is the largest for native flour (920 AU) and decreases in the model systems of wheat flour with an increase in the sautéing temperature and duration. Rational region of viscosity for the samples of model systems is 760...840 AU, within which there are indicators for the samples treated

over 10 min. at a temperature of 110 °C and over 5 min. at a temperature of 120 °C.

3. It was established that the thermal treatment of flour in the presence of a fat component at 110...120 °C has almost no effect on a change in color, though it changes its saturation in the range of 450...500 nm and is typical technological indicator of a given system.

Owing to this mechanism, which was established because magnitude η_{\min} approaches magnitude η_{\max} , stability of the model systems improves with an increase in temperature and duration of heat treatment within 0.91...0.98 compared with native flour (0.88). This allows us to argue about the effectiveness of applying the process of flour sautéing in the technology of a croquette mass under the following technological modes: temperature is 110...120 °C, duration is 5...10 min. That indicates the possibility to purposefully control the processes of forming the structural characteristics of a croquette mass by adjusting its technological properties in the process of hydrothermal treatment.

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