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CRITERIAL FEATURES OF THE STRUCTURAL CHARACTERISTICS OF FINE-TEXTURED POULTRY MEAT

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Abstract. Poultry meat mechanically separated from carcases of broilers has been investigated and compared with hand-deboned minced meat. The values of the critical shear stress in the samples of hand-deboned meat were larger (on average by 1.3 times) than in the samples of mechanically separated meat with a similar physicochemical composition. The hand-deboned meat samples had by 1.4 times higher values of plastic viscosity, and the values of their consistency coefficient, too, were higher, on average, by 1.5 times. For both hand-deboned minced meat and mechanically separated poultry meat, the effects of the moisture and fat content on the rheological state of the samples (which is expressed by the consistency coefficient) are interrelated, since an increase in the fat content causes a corresponding decrease in the content of moisture. The defining parameter is the fat content: the higher it is, the lower is the resistance to shear stress in the samples of both masses investigated. On the other hand, if the fat content of mechanically separated meat increases to more than 15% and that of hand-deboned minced meat to more than 18%, this no longer determines the change in the structure, which is characterised by increased flowability. Samples of mechanically separated poultry meat with the fat content up to 12% and samples of hand-deboned minced meat with the fat content up to 15% tend to decrease in the viscosity and increase in the flowability. It has been found how the rheological properties of mechanically separated meat change in time. At the first stage (about 2–3 hours), the structure remains unchanged. During the second stage, all parameters reach their maximum values: this is the period of critical resting. Further resting (the third period) is characterised by a decrease in the numerical values of all parameters, which is explained by a decrease in the strength of the structure under the influence of a complex of microbiological and biochemical processes. The study of the rheological properties of mechanically separated meat of broilers and comparison of the obtained parameters with the corresponding characteristics of hand-deboned minced meat have afforded grounds for the conclusion about the possibility and practical value of using mechanically separated poultry meat in formulations of meat products.

Keywords: poultry meat, mechanically deboned poultry meat, manually deboned meat, minced meat, rheological characteristics, fine-textured meat.

Introduction. Formulation of the problem

Among the products of animal origin most promising in terms of their nutritional value, there are such emulsified meat products as Bologna-type sausages, frankfurters, and pâtés. In the composition of these products, comminuted meat forms a three-dimensional gel matrix, thus emulsifying fat, retaining native and added water, and performing other important technological functions [1,2]. This fully applies to poultry meat, especially broiler meat. This type of meat raw materials is popular with consumers due to its nutritional value, taste, and, last but not least, affordability. Since the problem of providing consumers with protein products of animal origin is important worldwide [3], the production and widespread use of broiler meat is one of the most practical ways to solve this problem. Along with minced poultry meat deboned by hand, poultry meat separated by mechanical means is widely used as a raw material for sausages and other products from comminuted meat. This term applies to technological masses of the widely varying quality, which depends, in particular on the content and nature of bone inclusions and on the structural characteristics. The latter, in many respects, determine the quality of finished products from comminuted meat [4]. In view of the above, it is important to study comprehensively the structural properties of raw poultry meat produced by manual deboning and those of meat masses separated by mechanical means (fine-textured meat).

Analysis of recent research and publications

More than 50 years have passed since the technological progress allowed effective mechanical deboning of meat-and-bone residues to obtain valuable protein-containing raw materials – mechanically separated meat, in particular, mechanically deboned poultry meat (MDM). By its physical and chemical properties, MDM is similar to hand-deboned comminuted poultry meat (HDC), but it differs from it in a high content of bone tissue, bone marrow, connective tissue, and fat [5,6]. EU Regulation No. 853/2004 [7] defines mechanically separated meat (MSM) as the product obtained by removing meat from flesh-bearing bones using mechanical means resulting in the loss or modification of the muscle fibre structure [8,9]. According to [10,11], MDM, mechanically recovered meat (MRM), and MSM are synonymous definitions of the same material obtained by applying mechanical force (pressure and/or shear) to meat-and-bone raw materials, in particular, poultry carcases [8]. This classification is also referred to in [12], with addition of one more category that includes mechanically deboned chicken meat (MDCM), which, according to the authors, is of lower quality. However, commonly, the more general term "mechanically deboned poultry meat" (MDPM) is used [13]. According to [8], there are two forms of MDM production: using high pressure or low pressure machines, and the resulting masses are called, respectively, hard or soft deboned meat. Previously, in Great Britain, the latter raw material type was called desinewed meat (DSM), but now this term is out of use [14]. The Regulation [7] defines different requirements to MDM obtained by methods that do not alter the bone structure, and by those that change it and thus increase significantly the calcium content, compared with that in HDC. The changes in the meat structure during deboning and the character of these changes depend on the raw materials, the design and technical condition of the equipment, the processing modes, etc., that is why the norms defined in [7] do not provide a clear distinction between hard and soft deboned meat: whether it belongs to the first or second category is to be determined by a research study [15,16]. However, at the national level, such a classification can be introduced. In Ukraine, according to [17], all meat separated by mechanical means (MSMM) falls into MDM with the modified structure and MSM with the unchanged structure.

The structure and properties of MSM are similar to those of HDC. So, it makes sense to apply the HDC quality criteria to MSM, in particular, to its rheological properties. Minced meat, in terms of rheology, has a viscoplastic structure, with all its characteristic properties. The quality of minced meat directly depends on its rheological characteristics [18-20], in particular, the critical shear stress, effective viscosity, plastic viscosity, point of fluidity, and the like. Effective viscosity is the final variable characteristic describing the equilibrium state between the processes of restoration and destruction of the structure. The lower the value of this parameter, the more the structure is deformed under the influence of shear [21]. Technological (moisture, fat content, ageing duration) and physicomechanical (temperature, degree of grinding, or dispersion, pressure and vacuum) factors determine the changes in the shear properties: critical shear stress, plastic and effective viscosity, and other rheological characteristics [22]. As a result of an increase in the relative fat content, with the same moisture content and water holding capacity of muscle tissue proteins in the minced meat, water is displaced into the interior layer between the minced meat particles – the space between the particles increases, and the maximum shear stress decreases [23]. The rheological characteristics of intermediate technological minced meat masses and finished products from minced meat are determined by instrumental methods of studying their structure [24,25]. In particular, the penetration test is used to determine the shear stress [26-29].

Case studies of the rheological properties of MSMM in all its varieties are not numerous – neither were they at the time when it was an innovative raw material [30], nor have they been in recent years [31]. Some studies, for example [32], are devoted to the rheological properties of protein products with MSMM. The complex studies of MSMM described in [33-35] only indirectly relate to the rheological properties of the raw material in question. These properties are described in more detail in the sources [36,37]. Their authors come to the conclusion that changes in the technological properties (moisture content, fat content, pH) and processing methods (grinding, mixing) effect on the point of fluidity rather than on plastic and effective viscosity. It should be noted that the main object of rheological research is not actually MSMM, but numerous sausages and other meat products containing this raw material [38-42].

The purpose of the article is to study the possibility and practical value of using mechanically separated meat in formulations of meat products without worsening of their quality. For this purpose, the following **objectives** should be achieved:

1. Substantiating the criteria of classification of mechanically separated poultry meat as a rheological system.
2. Comparative studies of rheological parameters of shear in samples of mechanically separated meat and hand-deboned minced meat.
3. Determination of how the rheological characteristics of the masses under study depend on their physical and chemical parameters.
4. Study of the dynamics of the shear parameters of mechanically and manually deboned meat during storage.

Research materials and methods

The object of research was MSM from carcases of broilers and hens of second-class quality, from necks and backs of broiler carcases, with a temperature from minus 4°C to 6°C. The MSM was produced at the Meat Processing Plant *Stolychnyi* (Kyiv) with the use of a screw press separator *Lima* [43]. The separator had the following specifications: power 30kW; productivity 600kg/h; MSM yield for carcases is 75–85%, for skeletons 60–70%; screw rotation speed 3s^{-1}; filter holes 0.3 or 0.5mm wide and 20mm long; content of bone inclusions in MSM not more than 0.2%.

Other study objects included broiler meat (skeletons, quarters with and without skin, legs, thighs, drumsticks, breasts) of manual deboning was minced with a grinder K7-FVP-160-1 (power 15kW, productivity 3000kg/h, diameter of the plates 160mm, diameter of the holes of the outlet plate 3 mm, rotation speed of the operating screw 2s^{-1}).

To study the physicochemical characteristics of minced meat masses, the following methods were used:

– determination of the mass fraction of moisture, according to DSTU ISO 1442:2005 “Meat and meat products. Determination of the moisture content (reference method)” (ISO 1442:1997, IDT);

– determination of the mass fraction of fat, according to DSTU ISO 1443:2005 “Meat and meat products. Determination of the total fat content” (ISO 1443:1973, IDT).

Samples of MSM with different moisture and fat contents M1 – M4 were studied. The reference samples of HDC were C1 – C4 with a similar moisture and fat content (Table 1).

The sources of the minced meat were different parts of hand-deboned broiler carcases. For the samples C3, C4 with a high fat content, meat from quarters with skin and thighs was used (80% of the composition), and for the samples C1, C2 with a lower fat content, from the skeletons and breast bones without skin (70% of the composition), the rest of the meat was taken from the legs and shanks. The MSM samples M1–M4 were made from the same parts of carcases as the corresponding HDC samples C1–C4.

Table 1 – Content of moisture and fat in the test samples

Samples of mechanically separated poultry meat (MSM)				
Sample	**Mass fraction of water, %**	**Measurement error not exceeding ±Δ**	**Mass fraction of fat, %**	**Measurement error not exceeding ±Δ**
M1	74.27	0.14	3.20	0.07
M2	69.88		9.84	
M3	66.56		15.34	
M4	62.79		20.79	
Samples of hand-deboned and comminuted poultry meat (HDC)				
C1	74.17	0.16	2.56	0.07
C2	68.11		12.37	
C3	64.71		18.05	
C4	64.28		20.38	

The shear rheological parameters of the masses were investigated on a universal electromechanical testing machine SANS CMT2000, model 2503 [43]. The viscosity was determined from the numerical values of the force applied when a cylindrical indenter passes a sample with a constant contact area, which corresponds to the indenter area, at a given indenter speed.

The critical shear stress (penetration) was determined using a conical indenter. All mathematical calculations of these parameters and the graphical processing of the results were carried out using the software Power Test DOOE V.3.6.

Results of the research and their discussion

The shear rheological properties of MSM were studied by parameters that are characteristic of minced meat systems with a viscoplastic structure [43-45]. The shear stress was determined by the formula:

$$\tau = \frac{F}{S}, \tag{1}$$

where τ – shear stress, Pa;

F – inner friction force, N;

S – contact area of the layers, m^2.

The data obtained have mad it possible to plot fluidity curves (rheograms) of the samples.

From the data obtained, the plastic (Bingham) viscosity η_{pl} has been found. It is determined graphically as the cotangent of the angle of incline of the approximating straight line to the horizontal axis:

$$\eta_{пл} = ctg\,\alpha = \frac{\tau - \tau_0}{\dot{\gamma}}, \tag{2}$$

where τ_0 – critical shear stress, Pa;

τ – maximum shear stress, Pa;
γ – shear rate, s^{-1}

The value of the critical shear stress was determined by P. Rehbinder's formula:

$$\theta_0 = K_\alpha \cdot \frac{P}{h^2}, \qquad (3)$$

where θ_0 – maximum shear stress, Pa;
P – penetration force;
h – cone penetration depth;
K_α – cone constant at α=60°.

The consistency coefficient as a rheological parameter is determined by formula:

$$\tau = K\gamma^n, \qquad (4)$$

where τ – shear stress;
K – consistency coefficient;
γ – shear rate;
n – power-law dependence index (nonlinearity index).

The value of the parameter *n* indicates the power of the non-Newtonian liquid dynamics within a certain range of shear rates. The smaller the value of *n*, the more significantly the structure is deformed by the action of shear within the range of shear rates, and the less nonlinear is the graph of dependence of the shear stress upon the shear rate.

If we approximate the curve shown in Fig. 2 to the power-law dependence by the trend line, we obtain the dependence equation (4) with numerical values: $\tau = 1.21\gamma^{0.37}$, where the value of the consistency coefficient K=1.21.

Values of the effective viscosity are calculated using data on the shear stress τ and the corresponding values of the shear rate γ by the ratio derived from the formula (2):

$$\eta_{ef} = \frac{\tau}{\dot{\gamma}}, \qquad (5)$$

where η_{ef} – effective viscosity;
τ – shear stress;
γ – shear rate.

The dependence of the effective viscosity on the shear rate is the main characteristic of the rheological properties of minced meat systems.

Based on the shear stress and shear rate values determined by the above-described method, rheograms have been plotted to characterise the flow (deformation) of the samples. The rheograms of the MSM and HDC samples with different moisture and fat contents are shown in Fig. 1.

A preliminary analysis of the rheograms, or flow curves, of the samples, plotted in the coordinates $\tau - \gamma$ (shear stress – shear rate), can be done by the slope: its value characterises the degree of destruction of the structure. The larger the slope of a curve, the more destroyed the structure of the samples is. In the samples of hand-deboned minced meat C1 and C2 (those with a lower fat content), we observe a slightly larger slope in comparison with the similar MSM samples M1 and M2. The shapes and locations of the HDC and MSM curves being quite similar, we can see that the deformation of the MSM samples begins in a rather narrow area of low shear stresses (up to 500 Pa), and this is typical of all MSM samples, whereas the start of deformation of the samples C1 and C2 corresponds to the area of higher shear stresses. Obviously, this is due to the structural differences between MSM and HDC: MSM is always more finely ground than HDC, that is why MSM samples are more susceptible to deformation, even at low shear stresses.

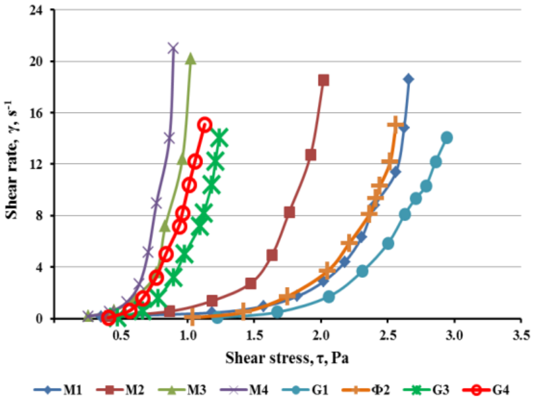

Fig. 1. Rheograms of the MSM and HDC samples

The location of the curves along the horizontal axis of shear stresses visualises greater differentiation between the samples C1, C2 (lower in fat) and C3, C4 (higher in fat), as compared with the similar MSM samples, which indicates a lesser effect of the fat content on the shear characteristics.

According to the above, by the formulae (2) and (4), the plastic viscosity and consistency coefficients have been calculated for each sample. The values obtained are given in Table 2.

Table 2 – Plastic viscosity and consistency coefficients of the MSM and HDC samples with different moisture and fat contents (n=3, p≤0.05)

Sample	Parameter	
	Plastic viscosity, $\eta_{пл}$, Pa·s	**Consistency coefficient, *K***
MSM		
M1	44.99	1.54
M2	33.40	0.93
M3	16.00	0.48
M4	13.54	0.46
HDC		
C1	56.39	1.89
C2	44.92	1.64
C3	22.41	0.75
C4	21.69	0.64

Analysing the values of the consistency coefficient K in Table 2, one can draw the following conclusion. In comparison with the MSM samples, the HDC ones have larger K values, thus are less flowable and, respectively, more viscous.

To describe completely and compare the structural and mechanical properties of the samples under study, the effective (structural) viscosity has been determined by the formula (5). Whereas the plastic viscosity is constant in a certain range of shear rates, the effective viscosity changes with a change in the shear rate. For each sample under study, the effective viscosity values corresponding to certain shear rate values have been calculated. To make the comparison easier, equations showing the dependence of the effective viscosity on the shear rate have been obtained for each sample and presented in Table 3.

Table 3 – Dependence of the effective viscosity on the shear rate of the MSM and HDC samples with different moisture and fat contents

Sample	Equation of dependence of the effective viscosity on the shear rate
MSM	
M1	$\eta_{efM1} = 1.54\gamma^{-0.79}$
M2	$\eta_{efM2} = 0.93\gamma^{-0.69}$
M3	$\eta_{efM3} = 0.48\gamma^{-0.72}$
M4	$\eta_{efM3} = 0.46\gamma^{-0.75}$
HDC	
C1	$\eta_{efC1} = 1.88\gamma^{-0.83}$
C2	$\eta_{efC2} = 1.61\gamma^{-0.82}$
C3	$\eta_{efC3} = 0.72\gamma^{-0.79}$
C4	$\eta_{efC4} = 0.61\gamma^{-0.78}$

The equations obtained allow calculating an effective viscosity value for a certain shear rate value from the measurement range for each sample. Effective viscosity is viewed as comprising plastic viscosity (which corresponds to the viscosity of a Newtonian fluid) and structural viscosity (which characterises resistance to shear caused by the structure-forming tendency of solid particles). Effective viscosity, which constitutes a significant part of the total shear resistance, decreases with increasing shear rate. The dependence of the effective viscosity on the shear rate is the main characteristic of the rheological properties of minced meat systems, since the effective viscosity is an integral characteristic that describes the equilibrium state between the processes of restoration and destruction of the structure. The numerical factor in the equations in Table 3 is, in fact, the viscosity coefficient, which characterises the degree of resistance to shear stress. The exponents in the equations of Table 3 show the rate of destruction of the structure. For example, its absolute value is the lowest in the sample M2, which indicates that the structure of this sample is destroyed to a lesser extent, in contrast to the sample F1, where its absolute value is the highest. Obviously, the difference in the values of the effective viscosity is explained by the different physical and chemical composition of the same-type samples, as well as by the different structure (initial state of grinding) of the MSM and HDC samples.

The next stage was devoted to determining the dependence of the shear rheological parameters on the physical and chemical parameters of the test samples. The values of the moisture and fat content in the samples are given in Table 1. Based on these data and on the values of the consistency coefficient determined for each sample (Table 2), the structural states of the viscoplastic mass (viscosity, fluidity) of the samples under study have been compared.

The effects of the moisture and fat content on the rheological state of the samples, which is expressed by the consistency coefficient, are interrelated: an increase in the mass fraction of fat causes a decrease in the mass fraction of moisture. Here, the defining parameter is the fat content. As can be seen from the data in Tables 1–3, for samples with a lower fat content (M1, M2 and C1, C2), the values of the numerical factor in the effective viscosity expressions (1.54, 0.93 and 1.88, 1.61 respectively) are larger than those for the samples with a high fat content (M3, M4 and C3, C4 – 0.48, 0.46 and 0.72 and 0.61 respectively). This indicates lower resistance to shear stress in the samples with a high fat content. On the other hand, a fat content higher than 15% for MSM and higher than 18% for HDC no longer effects on the change in the structure, which is characterised by increased fluidity. That is, the samples of MSM with the fat content up to 12% and the samples of HDC with the fat content up to 15% tend to decrease in viscosity and increase in flowability (fluidity). As a result of an increase in the fat content, the minimal viscosity no longer resists shear, which leads to the state of constant flow.

The dependence of the consistency coefficient on the mass fraction of moisture (Table 1, Table 2) does not comply with the well-known fact that with a decrease in the viscosity, the moisture content increases. Obviously, this dependence is true for minced meat with highly comminuted muscle tissue, processed at high pressures, due to which much of the bound moisture passes into the free state and, remaining between layers, reduces the shear friction, and, consequently, the viscosity. An example is MSM, produced on presses of hard impact. This dependence also arises when water is added to reduce the temperature during comminuting on cutters.

Thus, it has been found that excessive fat contents (more than 15% for MSM and more than 18% for HDC) adversely affect the integrity and viscosity of both masses. For the latter, this limit is somewhat higher, due to the lesser degree of grinding.

The obtained values of the critical shear stress of the MSM and HDC samples at the beginning of the research and during resting (ageing) have allowed plotting curves of changes in the critical shear stress of the samples throughout the resting time (Fig. 2).

Analysis of how the duration of resting (ageing) effects on the change of the critical shear stress has shown that during the first 3 hours, the properties of the samples studied hardly change, since during this period, the activity of meat enzymes is not too pronounced. This holds true for both the MSM and the HDC samples. After resting for 16hours, all samples showed some increase of the critical shear stress, its values being different for each sample. An increase in the values of the critical shear stress indicates an increase in the strength of the structure. Further resting causes a decrease in the values of the critical shear stress of all samples, that is, the structure loses its strength. Such a decrease in strength is explained by the intensification of the meat's own enzymes and the action of foreign microflora. It can be noticed that samples with a high fat content, both the MSM ones (M3, M4 – 15.34, 20.79% respectively) and the HDC ones (C3, C4 – 18.05, 20.38% respectively) are susceptible to ageing to a lesser extent than the samples with a low fat content (M1, M2 – 3.20, 9.84% respectively, and C1, C2 – 2.56, 12.37% respectively). Throughout the storage period, the samples high in fat had low critical shear stress values. In particular, after 48 hours of storage, the critical shear stress values of the samples M3, M4 and C3, C4 were, respectively, 413.7, 379.4 Pa and 714.3, 556.8 Pa. For the samples M1, M2 and C1, C2, these values were, respectively, 1126.4, 1089.7 Pa and 1521.4, 1423.6 Pa.

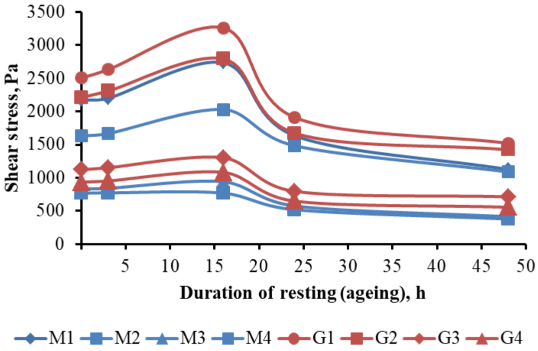

Fig. 2. Changes of the critical shear stress of the MSM and HDC samples during resting (ageing)

The somewhat lower values of the critical shear stress in MSM, as compared with those in HDC, are due to higher processing pressures, a greater degree of grinding both muscle and fat tissues, penetration of some part of the bone marrow into the fat, etc.

So, the technological features of the resting process of MSM manifest themselves in changing its rheological properties as follows. The ageing process is divided into three periods. The first is short (about 2–3 hours), during which time, the structure remains unchanged. The second is the period of growth of all parameters to the maximal value, this is the period of critical resting. Further resting (the third period) causes a decrease in the values of all parameters, which is obviously because the structure loses its strength under the influence of a complex of microbiological and biochemical processes.

An increase in the fat content causes a significant decrease in the values of all shear parameters and characteristics of MSM. The technological process of MSM production involves comminuting the raw materials by increased pressure, which leads to a more intensive destruction of not only muscle, but fat tissue as well. Due to the ingress of fat into the interparticle layers and to friction between them, the shear forces and the viscosity decrease in proportion to the increase in the fat content. Besides, the increased pressure during grinding promotes the release of bone marrow lipids from meat-and-bone raw materials MSM is obtained from. This is another factor that accounts for the reduced values of the rheological characteristics of MSM, in comparison with HDC where these raw materials are not used.

As a result of the studies, it has been found that, despite the similarities of the physicochemical parameters and the structures, the shear rheological parameters of the MSM and HDC samples have certain differences. Thus, in the HDC samples, the values of the critical shear stress determined by the penetration method are higher, on average, by 1.3times than those in the MSM samples with a similar physicochemical composition, which indicates the higher structural strength of the former. Also, the HDC samples have values of plastic viscosity higher by 1.4 times, which characterises the resistance to deformation under stress, which exceeds a certain limit (critical shear stress). The consistency coefficient of these samples is, on average, higher by 1.5 times. This coefficient reflects the structural state of flowable bodies. An increase in the consistency coefficient indicates a decrease in the fluidity: the higher its value, the higher the viscosity of the structure is. Since the HDC samples have higher values of this parameter than the MSM ones, their flowability is lower, and the viscosity, respectively, higher. Due to a relatively high pressure, the fat of the bone marrow gets into the MSM mass in the process of grinding. This, too, contributes to a decrease in the rheological parameters of MSM, in comparison with HDC where this factor is absent.

On the basis of these studies, a set of parameters and their limiting values close to the characteristics of HDC have been determined.

For the effective viscosity, as a variable characteristic depending on the shear rate, equations have been obtained that show the dependence of the effective viscosity on the shear rate. The coefficients in the equations, which correspond to the state close to the characteristics of HDC, have values 1.5 to 1.6. The values obtained can vary within these limits depending on many external factors, for example, on the temperature of the product and the time from manufacturing the samples to studying them.

During the research, it has been found that the most significant factor determining the difference in the rheological parameters of MSM and HDC is the fat content. A decrease in this indicator brings the rheological characteristics of MSM closer to the characteristics of HDC. This can be achieved by using raw materials with a lower fat content to produce MSM, by reducing the processing pressure to prevent additional release of fat from the bone marrow, and by reducing the rate of grinding the raw materials. Of course, these measures reduce the yield of the product manufactured, but significantly increase its quality.

Thus, the results of the studies performed have confirmed the ideas expressed in [21] that a decrease in the effective viscosity indicates a more significant deformation of the structure of the minced-meat-like mass affected by shear. It has been shown that technological factors (moisture and fat content, duration of ageing) effect on changes in the shear properties (critical shear stress, plastic and effective viscosity, and other rheological characteristics), which is consistent with the research results [22]. Thus, we can agree with the opinion of the authors [23] that with an increase in the relative fat content at the same moisture content and water-holding capacity of muscle proteins, the water present in the minced meat is displaced into the interlayers between the minced meat particles: the space between particles increases, and the maximum shear stress decreases. However, the conclusions [36,37] that changes in technological properties (moisture content, fat content, pH) and processing conditions (grinding, mixing) affect the point of fluidity rather than the plastic and effective viscosity, have found no convincing confirmation in this research.

Conclusion

The results of the research performed make it possible to qualify MSM as a rheological system, equivalent to HDC in its structural parameters. Analysis of the experimental curves plotted in accordance with the Bingham rheological equation has allowed establishing that the structure of MSM belongs to the rheological system of viscoplastic products and is characterised by a complex of features and parameters, of which the main ones are the critical shear stress and the effective and plastic viscosity.

It has been found that, despite the similarity between the physicochemical parameters and the structure, the shear rheological parameters of the MSM and HDC samples had certain differences. The value of the critical shear stress determined by the penetration method was higher, on average, by 1.3 times in the HDC samples than in the MSM ones similar in their physicochemical composition. This indicates that the structure of the former is stronger. The samples of HDC had by 1.4 times higher values of plastic viscosity, which characterises the resistance to deformation under stress exceeding a certain limit (critical shear stress). Besides, these samples had the values of the consistency coefficient higher, on average, by 1.5 times.

On the basis of the research, a complex of rheological parameters and their limiting values close to the characteristics of HDC have been determined. The principal rheological parameters and characteristics describing the structural state of MSM are: critical shear stress (penetration) – 1.9kPa to 2.2kPa; plastic viscosity – 33Pa·s to 45Pa·s; consistency coefficient – 1.4 to 1.7.

It has been found that during the first three hours of storage, the structure remains unchanged, from the 3rd to the 16th hour of storage, the values of the critical shear stress increase to their maximum. From 16 to 48 hours, there is a decrease in the values of this parameter. Thus, it can be concluded that the ageing process, which manifests itself as a change in the structure, occurs according to a similar pattern for both the MSM and the HDC samples, which confirms the similarity of the structural characteristics of MSM and HDC. The difference in the critical shear stress parameter is explained, in particular, by the different degree of grinding (the technological features of the manufacture of MSM and HDC).

This research of the rheological properties of mechanically separated meat of broilers and the comparison of the obtained parameters with the corresponding characteristics of hand-deboned minced meat have allowed assessing the possibility and practical value of using mechanically separated meat in formulations of meat products.

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КРИТЕРІАЛЬНІ ОСОБЛИВОСТІ СТРУКТУРНИХ ХАРАКТЕРИСТИК ТОНКОТЕКСТУРОВАНОГО М'ЯСА ПТИЦІ

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Анотація. Досліджено м'ясо птиці механічно відокремлене з тушок курчат-бройлерів та порівняно з фаршем з м'яса ручного обвалювання. Показники граничного напруження зсуву у зразках м'яса ручного обвалювання мали більші, в середньому в 1,3 рази, значення, ніж у аналогічних за фізико-хімічним складом зразках м'яса механічно відокремленого. Зразки м'яса ручного обвалювання відрізнялися більшими в 1,4 рази значеннями пластичної в'язкості, а також більшими, в середньому в 1,5 рази, значеннями коефіцієнта консистенції. Як для фаршу з м'яса ручного обвалювання, так і для м'яса птиці механічно відокремленого, впливи вмісту вологи та жиру на структурно-механічний стан зразків, виражений коефіцієнтом консистенції, є взаємозв'язаними, оскільки збільшення масової частки жиру викликає відповідне зменшення масової частки вологи. Визначальним показником у цьому разі є вміст жиру: чим він більший, тим меншою є величина опору зсувним напруженням у зразках обох досліджених мас. Водночас, збільшення вмісту жиру понад 15% для м'яса механічно відокремленого та понад 18% для фаршу з м'яса ручного обвалювання вже не впливає на зміну структури, для якої характерна підвищена плинність. Зразки м'яса птиці механічно відокремленого з вмістом жиру до 12% і зразки фаршу з м'яса ручного обвалювання з вмістом жиру до 15% мають тенденцію до зниження в'язкості та збільшення плинності (течії). Виявлено характер зміни реологічних властивостей м'яса механічно відокремленого у часі: впродовж першого етапу (триває близько 2–3 год) структура залишається незмінною, другий етап - період росту всіх показників до максимального значення, це період критичного витримування. Подальше витримування (третій період) характеризується зменшенням числових значень всіх показників, що пояснюється зниженням міцності структури під дією комплексу мікробіологічних і біохімічних процесів. Дослідження реологічних властивостей механічно відокремленого м'яса курчат-бройлерів та порівняння отриманих показників з відповідними характеристиками фаршу, утвореного шляхом подрібнення м'яса ручного обвалювання, дало підстави для висновку про можливість і доцільність залучення м'яса механічно відокремленого до складу м'ясних виробів.

Ключові слова: м'ясо птиці, м'ясо птиці механічно відокремлене, м'ясо ручного обвалювання, фарш, структурно-механічні характеристики, тонкотекстуроване м'ясо.

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