TECHNOLOGICAL ROLE OF ANIMAL FATS IN THE PRODUCTION OF COMMINUTED MEAT PRODUCTS

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General information on the structure of sausage emulsion and on its formation

The problem of animal fats utilization in sausage production has two aspects: one is associated with fat effect upon sausage food value, the second - with the necessity of fat rational and as wide as possible use on the commercial scale.

Any property of any body depends both on the composition and on the structure of the latter, and many technological processes have the purpose to effect such changes in the composition and in the structure to convert them into a food product with pre-set properties and are summarized in the concept the quality of this product.

Among obligatory properties of foods the following should be mentioned (not going into details): high food value, safety for humans'health and the appearance by which consumer's primary judgement of a product is formed. Along with this, of no less importance from the economic point of view is the task of obtaining the maximum yields of the product and of keeping to the requirements of standards or other official documents concerned with product composition.

Obviously, the above-mentioned should be taken into account when dealing with the problem of fat rational use in the technological processes for sausage production.

The food value of edible fats is the topic of another review. Realizing their high food value, one may limit himself with stating that their content in many sausages is sufficient to satisfy the requirements of human organisms. But being a product component, fat affects the food value of this product as a whole. Experiments on humans allowed to establish that the kind of fat and the ratio fat/protein in the products affect the digestibility of both components. A higher fat content retards the secretion of the gastric juice and protein digestion by pepsin. On the other hand, by provoking the pancreas, fat stimulates the secretion of pancreatic juice not only for itself, but also for nitrogenous substances and carbohydrates /15, 26/. When feeding dogs with meat and pork fat (protein/fat ratio is 1:1), it was observed that the latent period was extended; pepsin level in the gastric juice and acidity were reduced; a similar amount of juice was secreted within twice as long a period as compared to feeding dogs with meat only. Increasing fat content aggravates these phenomena. On the other hand, the pancreatic juice, stimulated by fat, had higher contents of protein and enzymes, as compared to stimulation by meat /47/.

Thus, first, with account for the normal fat requirements of the human organism, one should assume the existence of an optimum ratio of protein to fat which enter the organism at a single time. Second, it is obvious that the longer and the more complete fat emulsifying, the quicker its removal from the stomach and the easier protein digestion.

In literature there is no special data available on the optimum protein/fat ratio, which enter the organism at a time, when consuming meat, but, obviously, this optimum should not differ greatly from the ratio recommended, on the average, for a daily ration, i.e. 100:100 /8/, with lipids containing about 8 units of highly unsaturated acids; the maximum fat/protein ratio is appr. 350:250. There is an assumption that the optimum fat content in meat products should constitute 75% of the available protein.

Meat products are, as a rule, eaten together with bread, containing proteins; therefore it may be assumed that, under the commercial conditions and proceeding from the permissible quantitative ratio of lipids to protein, it is expedient to manufacture three kinds of sausages:

- those for general use, which contain optimum fat (about 20-22% as fatty tissue);
- those of a high caloric value, which contain maximum fat (up to 25-26% as fatty tissue);
- those for dietetic purposes, in which fat content is below the optimum.

As was mentioned above, however, the food value of a product depends not only on its composition, but also on its structure. As far as sausages are concerned, there are two important aspects: 1) their structure as a whole, i.e. the spatial distribution and the association of protein and fat components; and 2) of no less importance is the struture of the fat component proper.

With respect to cooked sausage products, including canned comminuted meats, their fat components can be present as bigger or smaller pieces, as fatty tissue decomposed to this or that extent (e.g. in frankfurters or sardellas), or as melted fat. Judging every above version from the viewpoint of the effect on product food value, one should bear in mind that fat decomposition by pancreatic lipase must be preceeded with the destruction of the protein base of the fatty tissue structure and fat removal from the stomach. Since collagen is the main connective tissue protein, which is comparatively difficult to decompose by pepsin and trypsin even after heating, it suggests that the process of the destruction of the protein base of the fatty tissue will be rather slow; the bigger fat pieces size, the slower the process, and vice versa. Obviously, the finer comminution of the fatty tissue, the better. The above-said is valid for raw fat contained in sausages.

During comminution of sausage emulsion components, in a cutter, mechanical destruction of the tissue predominates, this being followed by their intensive swelling promoted with added water. When being destructed, muscle fibers are cut, mainly, across their axes, and their contents are released. Some muscle bundles are cut along fibers axes into separate fibrils. The prevailing size of the particles does not exceed several microns. When swollen, these particles form a grainy mass with semi-destructed muscle fibers, scraps of connective and fatty tissues, blood and lymphatic vessels, nerve fibers, fat cells, as well as dispersed fat particles - of oval or, more seldom, spheric shape - incapsulated with structured protein which, mainly, contains collagen /52, 53, 58, 69, 74, 91/. The presence of the latter indicates partial emulsifying of fat.

Fat emulsifying during comminution results in a significant local temperature rise, this causing material spot overheating and fat melting. The formation of a highly disperse emulsion is possible at intensive mechanical treatment of fat. The destruction of fatty cells gives a fine, disperse, stable emulsion.

A preparation of the meat component of cooked sausage emulsion looks like a finely-grained, pale-rose mass with inclusions of scraps of muscle bundles and fibers, connective and fatty tissues, dispersed fat particles, cavities filled with gellied glutin on their inside surface /54/.

Thus, during comminution in a cutter only some fat (its amount depends on conditions) is released from the cells, forming emulsion. But tissue destruction and fat emulsifying are never completed.

Proteins are partially solved and pass to a continuous phase. These proteins, especially contained in the actomyosin fraction, determine sausage emulsion cohesion and post heat processing form a continuous spatial carcass which conditions the binding of product structure and in the cells of which insoluble particles, including those of the fatty component, are immobilized /44, 55, 69, 80, 83/. The strength of bonds between the particles of this component and product structural elements is determined both with the degree of fat emulsifying during cutting and with the participation of the fatty component in structure formation during heat processing.

On the basis of the specific mechanism of protein-lipid foods digestion one should assume that melted fat inclusion into a sausage emulsion may be expected to have the most favourable effect on product food value. But here a sufficiently high degree of the dispersity of the fatty component of the sausage emulsion must be provided.

The importance of product structure is not confined only to its effect upon the food value of the product. On its peculiarities depend a number of other quality characteristics and product yield. This forces us to consider in detail structure formation of a raw sausage emulsion and of the finished product. Numerous investigations showed that this is quite real on the basis of the propositions of physico-chemical mechanics of dispersed systems, which are developed by P.A.Rebinder and his coworkers /27, 38/.

Raw sausage emulsion by its structure and properties approaches dispersed systems of a coagulation type. In such systems dispersed particles are bound with each other by means of loose coagulation links determined by excessive surface energy and operating through a dispersion medium. These links are inclined to thixotropy, and due to this the whole system possesses thixotropic properties and is capable of flowing if the operating tangential stress exceeds the limit shearing stress. Their properties, therefore, can be fully enough expressed in rheological characteristics /3, 9, 10, 11, 12, 13, 14, 45, 46, 73, 103, 104/.

The basic structure-forming material of sausage emulsion is proteinaceous substances, lipids and water which predominate quantitatively in it /44, 68/. Some minor substances affect the properties of sausage comminuted meat structure (e.g., electrolytes). Probably, the strength and stability of its structure as a whole is directly connected with the firmness of links among all three structure-forming components, which must be sufficient to prevent the system from breakage during subsequent heat processing.

Taking into account the properties of raw sausage emulsion and the condition of its components, it should be emphasized that the continuous phase of its structure is liquid and contains soluble proteins, numerous soluble organic substances and electrolytes, and the discontinuous phase is represented by particles of a protein and lipid nature of various sizes up to those typical of colloidal systems.

Since the continuous phase includes both globular and fibrillar proteins of an elongated shape, loose aggregates are formed filling the whole volume of the sol. An elastic thixotropic carcass is developed, in which unsolved particles are distributed. The fibrillar structure of the continuous phase is observed under an electron microscope /55/.

Particles of the discontinuous phase in this complex system are connected by means of proteins dissolved in the continuous phase via interactions with them through solvate membranes fixed by hydrophilic centres. The strength and stability of raw emulsion structure, therefore, depends entirely on the ability of both protein and fatty components to interact with water.

Besides, similarly to other dispersed systems, the properties of sausage emulsion are related to the volume of dispersed particles in the systems, to their nature and especially their size and shape.

Of special importance is solubilization of the proteins of the actomyosin fraction during meat ageing in cure and subsequent intensive comminution /44, 79, 80/. Their solubilization is conditioned with the fact that added salt makes up the concentration of an electrolyte, which is close to the solvent one. A favourable effect of protein solubilization of the actomyosin fraction upon the processing properties of sausage emulsion is well known from the experience of warm meat use, in which actomyosin is, to a considerable degree, dissociated into actin and myosin having higher solubility. The addition of pyrophosphate, resembling by its action ATP, to chilled meat (after rigor)makes the properties of the latter close to those of warm meat /7, 32/.

A positive role of the proteins of the actomyosin fraction in fat emulsifying and emulsion stability was proved experimentally. This will be discussed later.

Necessary prerequisites for the formation of the proper structure of the emulsion - such as a due degree of dispersion and particles structure, a uniform distribution of constituents - are formed in the process of intensive comminution of its components. The formation proper of emulsion coagulation structure occurs during settling (holding prior to heat processing).

Studies into the changes of emulsion rheological properties and particles dispersity in the process of comminution in a cutter /11, 12, 22, 24/ showed that initially, on the background of a sharp increase of dispersion degree, a considerable reduction of viscosity and the limit shearing stress take place in parallel to stickiness growth. The character of these changes corresponds completely to the concept of the predomination of the destruction of tissue native cellular structure. Then, along with the proceeding increase of dispersity and stickiness, viscosity and the limit shearing stress start to grow up a certain maximum. This can be taken as an evidence of the initiation of the formation of a new structure. Upon reaching the maximum, the rheological characteristics decrease, stickiness is also reduced, though dispersity continues to grow. An undesirable change of the structure is observed, which is termed "super-cutting" in commercial practice. The cause of this phenomenon is local superheating of the mass, being comminuted, up to or above 100°C. Partial denaturation and coagulation of the proteins of the continuous phase and of those, forming a structured protective coating of the dispersed particles of the fatty component, result. Finished product structure is loosend, and during heating bouillon and fat are released.

Characteristic changes of emulsion rheological properties during comminution in a cutter can serve the basis for the determination of the optimum cutting time and of the amount of added water as related to emulsion composition /11, 12/. They are also usuful for developing the systems of automatic regulation of the process of cutting /1, 5, 19/.

There is a regular connection /44/ between rheological and surface characteristics of a raw emulsion, on the one hand, and structure strength and coherency and product yield, on the other hand. This allows 1) to solve the problem of selecting raw materials with the purpose of getting definite properties and yield of the product; and 2) knowledge of the character of the bonds opens prospects for the automatic regulation of the entire process of sausage emulsion preparation.

For rheological properties, the character of the above-mentioned binding is not, however, simple. Sometimes, this binding is direct: strength characteristics and coherency of the finished product structure increase with growing values of emulsion rheological properties. Such is, for example, the effect of meat ageing in cure /23, 39/. In other cases this binding may be reverse: reduction of rheological properties corresponds to increased structure strength and coherency of the finished product, as was mentioned earlier.

This aspect is still little investigated. However, it was proved experimentally that there is, as a rule, a direct connection among emulsion stickiness, structure properties and finished product yield /44/. This is quite natural as of the decisive role in the formation of finished product structure is that part of proteins which is solubilized in the raw emulsion and determine the value of stickiness. It should be noted, however, that the true charawter of the relationship among stickiness and product properties and yield is vivid only under such definition of "stickiness" when its main constituent is cohesion, rather than adhesion of the emulsion. At an increased fat content in the emulsion the relationship may become reversed /25/.

The coagulation structure of emulsion as such after it is prepared and stuffed at a high flow rate from the stuffing horn turns out to be entirely broken. Its stabilization and final formation, as is necessary for getting a product of proper quality and yield, takes place within the 2-3 hrs of settling. Of critical importance for structure stabilization are also that part of the proteins of the actomyosin fraction, which is solubilized, and protein ability for thixotropy.

Fat component participation in the formation of emulsion structure

In the light of this report, the main attention is given to the mechanism of fat component participation in structure formation of both raw emulsion and the finished product. Irrespective of the condition, in which it is added to emulsions (fatty tissue, melted fat), of importance are its amount and the strength of its binding to other structural elements of the system in question.

As for fat amount, which may be recommended with due regard to product food value, it was discussed earlier. Concerning the amount of fat permissible without any risk of significant coalescence during heating,under the convenient manufacturing conditions for products of a macroscopially homogeneous structure it should lie within 20-30% (as fatty tissue) /102/.

As was already mentioned, sausage emulsion should be considered as a dispersed system of protein-water-fat type. Water is a quantitatively prevailing component and participates directly in the mechanism of other components binding into a structure. The strength of binding of the fat component in this structure and its probable amount retained by the structure, apparently, depend, to a great extent, on the quantity of fat which forms direct emulsion during comminution in a cutter. By the way, it is a direct, rather than reverse emulsion, that influences favourably product flavour /37/. It is, obviously, determined with the fact that flavouring substances, which can irritate the nerve-endings of the organs of taste, are sorbed by the surface layer of dispersed particles. In the reverse emulsion they are isolated inside them.

In those cases when fat is introduced to the emulsion as fatty tissue (fat or semi-fat meat), the amount of fat which is emulsified depends on the conditions of intensive comminution of the raw materials(specifically, in a cutter). These conditions include: meat grade and state; protein-fat ratio; the amount of added water; the order in which various components are charged into a cutter; the temperature of the mass being ground; the intensity of comminution; process duration; the availability of substances contributing to the formation of fat emulsion (in this case the term "emulsion" is conditional as some fat is dispersed in the solid state).

From the viewpoint of product food value and other quality characteristics, as well as production economy, it is disirable that the amount of emulsified fat be as high as possible, the resulting emulsion be direct and its stability be sufficient to prevent its coalescence during heat processing. Thus, it is not only a question of fat emulsification, but of the stabilization of the resulting emulsion. As electron-microscopic studies showed, even small-sized fat dispersed particles (about 0.1 mc) may coalesce during heating to destruct the protective surface layer /55/. In finished frankfurters there may be found 2-30 mc droplets, the largest ones being located predominantly closer to the surface /34/. The specificities of the mechanism of emulsion formation, as applied to the conditions of sausage emulsion preparation, require further elucidation.

The resulting emulsion is considered concentrated, the size of dispersed particles being 1-10 mc (coarsely dispersion), 0.1-1 mc (medium dispersed), less than 0.1 mc (colloidally dispersion). Strictly speaking particles larger than 10 mc cannot be considered dispersed. The stability of concentrated emulsions is determined with structural-and-mechanical properties of the adsorption-solvate layer which results on particles surface. They are stable if adsorption layers have high structural viscosity and mechanical shearing strength. The effective thickness of the structured layer is 0.2-0.9 mc for the largest particles. Fig. 1 shows schematic structure of direct (a) and reverse (6) emulsion /17/.

The strength of the structured surface layer is specially important, if the effect of the mechanical destructive factor is taken into account during comminution. Properties necessary for this are inherent with stabilizers of combined nature, one of them possessing high surface activity and the other being able to form mechanically-strong structures. Solid-like (quasi-solid) properties of such structures are conditioned by the orientation of the particles which form them /40. 41/. To get direct emulsions, stabilizers-hydrophilic colloids - are needed.

Of the substances contained in sausage emulsion, soluble proteins, especially, of the actomyosin fraction are able to form strong structured layers /66, 78, 85/. Due to this, they contribute to the formation of heat-resistant emulsions /56, 61, 62,75, 79, 81, 97, 99/. Most effective are myosin and actomyosin /74, 76, 106, 107/. It is associated with their structure and inclination to thixotropy. The ability of solvate layers to thixotropic reconstitution is of significance in connection with possible emulsion inversion (phase inversion), i.e. direct emulsion conversion to the inverse one. This possibility is greater with a larger share of fat component and higher intensity of dispersion. It is especially great at simultaneous comminution of all the components in the machines of high capacity. Due to myosin and actomyosin thixotropic properties, sausage emulsion coagulation structure is stabilized, including fat component, during settling.

Myosin positive effect on fat emulsion stability in the sausage emulsion emphasizes the importance of the conditions and procedures for increasing the solubility of actomyosin fraction proteins during sausage emulsion preparation. The significance of this factor both for product structure formation and fat component stabilization in this structure was discovered in commercial practice long before the existence of these proteins became known. It is with this that warm meat utilization for cooked sausages is connected, which is added to sausage emulsion as so-called "prat".

In warm meat actomyosin is mostly dissociated into actin and myosin, which are easily soluble in the presence of an electrolyte NaCl. If this electrolyte is added to comminuted meat prior to the fast stage of rigor mortis, the latter is sharply slowed down due to the inhibition of ATP-ase activity of myosin and glicolysis /30, 31, 70, 71/, and, probably, as a result of electrostatic ionic effect /74a/. In the sausage emulsion, made of warm meat, dispersed fat particles are nearly spheric in shape and more uniformly sized /59/.

Reduction of the solubility of actomyosin fraction proteins, following rigor development, is accompanied with their decreased emulsifiability /108/. It should, however, be emphasized that sausage of fresh warm meat only has extremely hard and elastic texture, this being due to the development of a strong spatial carcass as a result of denaturation and coagulation of most dissolved proteins of the actomyosin fraction. It is, therefore, preferable to add up to 20-25% cured warm meat of the total.

Actomyosin dissociation can be stimulated artificially. E.g., it was experimentally proved that pyrophosphates action is similar to that of ATP /32/, which dissociates actomyosin. Tendency towards actomyosin dissociation is also contributed by polyphosphates/74/. Of a positive role is medium pH rise: emulsion stability increases with sausage meat pH growth /59, 60/.

Phosphate action is, however, more diverse. It is doubtless that they stabilize directly the structure of the protective layer of dispersed fat particles. Water-fat emulsion, containing 0.75% gelatine and 0.1% acid orthophosphate as stabilizers, was not decomposed after re-heating and cooling, whereas emulsion without orthophosphate was much less stable /41, 42/. Besides, polyphosphates partially saponify fat.

Phosphate application to improve and stabilize sausage emulsion structure is widely accepted in common practice. In many countries polyphosphates are preferred, in the USSR - pyrophosphates. Harm-free use of phosphates in limited amounts has been tested on animals /88, 95/. By their toxicity, they do not differ from commonly used flavouring additives. The United Committee of experts on food additives of the FAO (UNO) limited the permissible dose by 30 mg/kg of human weight (expressed as phosphorus).The USSR Ministry of Health restricted phosphates by 0.3-014% of the raw materials. Polyphosphates change notably product structure and flavour, however.

A favourable effect of the proteins of the actomyosin fraction on the stability of water-fat emulsion and on the formation of the spatial carcass, determining product structure, makes urgent the task of utilizing proteins of the meat, left after boning, e.g., on vertebrae, by extracting them with electrolyte solution /14/.

Globular proteins, including sarcoplasmic ones /75, 106,109/, have a lower stabilizing effect, but still sufficient to prove the expediency of utilizing such proteins to stabilize sausage emulsion structure. Due to their easy solubility they enrich the continuous phase of the emulsion; therefore, the stabilization of the fat component in sausage emulsion structure is also achieved through fat droplets immobilization in carcass cells. As a result, the probability of fat coalescence during heat processing is reduced.

The solution of the problem of the commercial use of globular and other soluble proteins as a component of sausage emulsions is connected with the evaluation of their effect on product food value and of economic expediency. In this respect, of interest are blood plasma (serum), milk proteins, soya proteins.

In the meat industry of the USSR serum (plasma) addition to some sausage emulsions is limited by 10%. The amino acid analysis of sardellas with 20% blood serum added did not reveal any significant differences from sardellas without serum, which could evidence a marked reduction of product biological value /40/.

Non-fat milk powder contributes to fat emulsion stabilization /83, 85/ and has a favourable effect on product food value, but it does not increase sausage emulsion water-binding capacity, obviously, because of an increased content of calcium salts /55a/. More effective are milk protein preparations, e.g., sodium caseinate.

As for soya proteins, their utilization as an additive to sausage emulsion should be based on their considerable influence upon product quality. Though these proteins contain all the indispensable amino acids, the biological availability of the latter is much lower as compared to those of meat proteins.

Taking into account the role of actomyosin proteins in emulsion formation and stabilization, the necessity of adjusting both muscle, fat and connective tissue ratio in the composition to the sausage emulsions should be admitted. With increasing connective tissue content, emulsifiability and stability of emulsions are decreased /86/.

The best organoleptic scores are given to products with the optimum fat-muscle ratio. Thus, Doctorskaya sausage made of prime-grade meat was best scored when it contained about 20% fat.

Under the conditions, when water predominates quantitatively in the system, the latter as a whole is stable only in case protein and fat can interact with water in such a way that particles polar groups are blocked by its molecules. Under-estimation of the role of fat component as a full-value one in the total structure of sausage emulsions results in incorrect practical recommendations, in which the ultimate effect is related to the properties of the protein component only.

Provided proteins, fat and water, held by the polar groups of protein or dispersed fat particles, participate in structure formation they will be attracted by water, held by these particles, not stronger than water molecules are attracted to each other. Hence, joining of two such particles will not increase energy, this determining system stability as a whole.

The mechanism of protein and protein structures hydration is well known, and there is no need to deal with it in detail in this report. The character of interactions between dispersed fat particles and water is clear from the scheme in Fig. 1.

Leaving the question of structure complication of direct-emulsion solvate layers (Fig. 1a), caused by the presence of electrolytes and other solubles, one should process from the idea of the development of multilayered water membranes. By some data /18/, the integral energy of hydration for natural polymers approaches 80 cal./g. Thus, with decreased solvate membranes thickness, interaction energy of hydrated particles increases. The whole system becomes stronger. And vice versa.

Since the orientation of water particles in the solvate layer imparts solid-like (quasi-solid) properties to it, in cases product particles are separated with sufficiently thin water interlayers, the system, on the whole, acquires certain hardness and mechamical strength. When the thickness of the interlayers is increased, they act as true viscous liquids, performing the role of a hydrodynamic grease. The system is plasticized, its fluidity grows. Further thickness increases cause system destabilization.

Taking into account the ability of fat dispersed particles to hydration, with the structured surface layer participating in this process, the active role of the fat component in the changes of the above properties of the system should be admitted. The strengthening of forcemeat structure by means of properly prepared emulsions, which increase greatly the water content of the former, was proved experimentally /43/.

Sausage emulsion structure depends on the ratio of the main components. With fat increases, viscosity of the intact structure decreases, this being especially sharp with fat content growth up to 30% or over, as fat acts as a plasticizing agent. This is determined by the fact that the strength of bonds, retaining fat dispersed fat particles in the system, is comparatively small. Fat possesses such an effect at about 20°C. Temperature fall in sausage emulsions causes a considerable rise in their voscosity as a result, in particular, of fat structural changes. The above regularity is established equally both for raw and melted fat in sausage emulsions.

When fat content in sausage emulsions is increased, shear modulus E also grows, this being determined by the formation of crystallization structures in fat, for which E is higher than for coagulation ones. Sausage emulsion stickiness is decreased because of a reducing level of the protein dissolved in the liquid phase, this reduction being caused by decreasing amounts of protein substances in the sausage emulsion.

While fat content in emulsion products grows, their tenderness is decreased, when these products are eaten cold; when they are heated, the difference is not so marked.

Thus, changes in fat content affect the structural-and-mechanical properties of both sausage emulsions and finished sausages.

On the basis of the above-stated on the participation of forcemeat main components in structure formation, the availability of "free water" in the structure of properly prepared sausage emulsion should be considered incorrect. Even that part of water, which is released (often together with fat) during heat processing because of physico-chemical changes of forcemeat structural elements, is bound water. It is more precise to differentiate water contained in sausage emulsions by bonds strength. For the technological purposes, the following dynamic scheme is convenient /18/:

strongly-bound water	⟶ ⟵	loosely-bound water, useful	⟶ ⟵	loosely-bound water, excessive

For sausage emulsions loosely-bound useful water is that giving the product plasticity, juiciness and other favourable organoleptical qualities. Excessive loosely-bound water is that which is separated during heat processing (often, together with fat).

This scheme can serve the basis for the term "water-binding capacity". Its quantitative expression must, obviously, characterize both water capacity of the material and the amount of strongly-bound water contained in the latter.

Of course, the application of the scheme suggests the necessity of certain standardization of the method for the determination of strongly-bound water content. Various methods used in the meat industry, yield different results, most often being far from the true ones. For sausage products, perhaps, the closest to the truth result was obtained by means of the method based upon the determination of non-soluting volume /6/. By the results of these investigations it can be suggested that the most favourable proportion between strongly- and loosely-bound water in a product should lie within 1:1.8 to 1:1.9, i.e. strongly-bound water must constitute 34-36% of the total water at the standard moisture content of the product.

Ways and methods for increasing the water-binding capacity of the protein component of sausage emulsion are universally known, and there is no need to speak about them now. As for the fat component, the following factors should be emphasized which depend greatly on the conditions of sausage meat homogenization (comminution): the amount of emulsifiable fat, the degree of emulsion dispersion and the strength of the solvate layer of dispersed fat particles.

In this connection I am going to touch upon the order in which sausage emulsion components are homogenized. Since of the critial effect upon fat emulsion stability is the participation of actomyosin proteins in the formation of the protective layer, it is desirable that the destruction of the muscular tissue be most complete. To provide the maximum solubilization of actomyosin proteins, non-fat meat must be fed first to the cutter. The rate and the degree of comminution in a cutter depends on the value of materials head resistance to the cutting device. Therefore, ice or water must be added to the mass, being comminuted, some time later (after about 20% of cutting time). And only after visual dissapearance of the added water (ice) semi-fat and fat meat must be fed. Practical experience of many years proved the efficiency of such an order.

A higher speed of comminution contributes to better dispersion of fat /49/. At the same time, the intensive effect of the cutting device on the sausage emulsion is accompanied by the development of much heat and a rise of the average temperature of the mass. The latter, on the one hand, promotes fat dispersion, this being conditioned by a comparatively low temperature of the first melting point of fat, which lies within 8-14°C /105/. However, local super-heating of the mass (see above) can be accompanied by emulsion destabilization. At temperatures above 15°C dispersed fat particles are decomposed and join to form bigger ones. At 20°C this process becomes significant /69/.

In view of the influence of homogenization conditions on fat emulsion stability, of practical interest is the question, little elucidated, of the usability of the cutting device in high-speed comminutors. Apparently, energy consumption for friction overcoming has decisive importance in the evaluation of cutters fitness. The greater friction of the cutter used, the greater probability of local super-heating, emulsion destabilization and direct to inverse emulsion conversion. Comparative experiments on sardella production, with the components being comminuted in a cutter in a colloid mill of the PUK VIKOSATOR type, indicated that in the latter case both the raw emulsion and the finished product were more plastic, of better water-binding capacity and with more uniformly distributed components; the yield of the finished product was higher /44/. In frankfurters manufactured by means of application of high-speed knife-plate-type comminutors, fat droplets are found, product consistency is too plastic and loose; the flavor becomes worse if ready forcemeat is processed in a cutter.

Fat emulsion application

Theoretical concepts about the character of bonds among the main structure-forming elements - proteins, fat and water, about the distribution of strongly-bound water between protein and fat suggest the expediency of more controlled dosing of muscular tissue and fat. Partially, this tendency is revealed in complete fat-muscle separation and in their subsequent precise metering /63/. With all the advantages and high labour consumption of this practice, the process of fat emulsion formation from the fat added remains essentially uncontrolled. Finished product quality and yield can vary with the properties and the composition of the fatty tissue, comminution conditions of emulsion components, etc.

In principle, it is possible to add melted (pure) fat to a comminutor both in the liquid and the solid state. But heated fat aggravates comminution conditions and solid fat is emulsified poorly and distributed unevenly. Emulsion is less stable as compared to that from the fatty tissue. When using melted fat, a higher percentage of phosphates is needed for stabilization, viz., 1-2% /101/. A better effect can be expected when ready fat emulsions are applied.

The expediency of ready fat emulsion application in commercial practice is determined by the quality of the resulting produce and by the economy of production processes. Both factors require exhaustive and objective evaluation. The advantages of ready emulsions are, quite apparently, in that their application makes it possible to use such fats and oils, which are of dietetic importance, and allows to add a metered mixture of pork and beef fat to sausage mixes. Such emulsions provide a uniform distribution of fat in the structure of sausage emulsions.

Fat emulsions favourable effect on some qualities is obvious from the above-stated. In particular, a product, manufactured with a fat emulsion added, has better organoleptical characteristics (tenderness, juiciness, a less-pronounced fatty off- flavour).

Fat is not separated from the emulsion even at canning by heating /102/, this eliminating fat pockets. But most important is emulsion effect upon product food value. According to the data in literature sausage products with fat emulsions added are harmless /88/ and of higher digestibility /28, 29, 90/. When feeding rats with sardellas containing fat, added as an emulsion with a protein stabilizer, an intensive secretion of the gastric juice, hydrochloric acid, pepsin and trypsin is observed. In general, these sardellas digestibility was by 2-3% higher as compared to that of traditional ones /28/.

Less clear is the economic aspect of the problem of fat emulsion application, which requires extra expenses for fat-muscle separation, for fat extraction and emulsion preparation. Some connective tissue, containing fat, does not enter sausage emulsion. But, on the other hand, this modification of technology provides higher and more stable yields of the finished product, its improved quality and lesser wastes. The loss of the connective tissue during fat melting can be offset by its lesser trimming from meat. It is also worth mentioning that fat emulsions render it possible to precisely meter components of the sausage emulsion, to control automatically the process of sausage mixture preparation and to take stock of the production exactly. As a result of improved water-binding capacity of the sausage emulsion meat holding in cure is eliminated. These statements are enough, at least, to recognize the problem worthy of thorough studying.

The quality and the stability of water-fat emulsions depend on fat properties. Of great importance is fat melting temperature: the lower the temperature, the better fat emulsification. Fats, containing short-chain acid radicals, are emulsified better; those, containing radicals without double bonds, - poorer /56/. A relation is found between fat acidity and emulsifiability /96/. However, it is, obviously, determined not by the quantity of free fatty acids proper, but by the equivalent amount of mono- and diglycerides /102/. Fat emulsifiability depends also on its concentration in the emulsion.

Practically, the method and the procedure of emulsion preparation, emulsifier (stabilizer) kind and concentration, mixed component temperatures, processing time, vibration frequency are of great significance.

For emulsions preparation, various homogenisers, colloid mills, ultrasonic units turned out to be suitable. Of interest, from the viewpoint of simplicity in structure and operation and of dispersion efficiency, is a device with a hydrodynamic ultrasonic generator, which gives a much finer dispersion /19, 20/ as compared to a colloid mill. Emulsification time in this device is about 7 min. If locate several generators in succession, this device can be compared to a continuous installation.

It is widely accepted that, to get emulsions for sausage products, the best stabilizers are protein substances. This is natural because, first, protein substances render it possible to prepare a direct emulsion, and secondly, the structured adsorption layer formed by proteins is comparatively easily splitted by digestive proteases. However, as was stated above, the adsorption layers, formed by proteins only, are not stable enough. They may be strengthened by combining proteins with certain stabilizers, e.g., phosphates (about 15-20% of the protein emulsifier).

A satisfactory stabilizing effect has been achieved when utilizing salt-soluble proteins of meat /99/, milk (sodium caseinate), blood plasma /19, 23, 24, 25/, gelatine /42/. Slightly less efficient are soya proteins /20/. The choice of a stabilizer is dictated by concrete conditions of its application. E.g., for the productions, operating at meat packing plants, of practical interest are blood plasma (serum), and proteins extracted from food wastes, which are added to emulsions in the amount of 1.0-1.5%. For independent plants of practical importance are transportable stabilizers, e.g., dry milk protein, sodium caseinate (1.0-1.5% of the emulsion), gelatine. Soya proteins are expedient where soya beans are processed.

A number of reasons make worthy the use of gelatine with orthophosphate added (0.75-1.0% gelatine + 0.10-0.15% monosubstituted orthophosphate of the total emulsion) as a stabilizer. The application of this stabilizer is not limited by temperature as gelatine does not coagulate. And temperature is the factor, on which dispersion rate and degree as well as the use of hard-melting fats (e.g., beef fat) depend. The adsorption layer formed by gelatine is easily destructed by proteases. Experiments on gelatine use in a hydrodynamic ultrasonic device at 40-50°C and at 11.5 kcs yielded pork fat-in-water emulsion with the average diameter of the particles slightly less than 2 mc, the amount of finely-dispersed particles being over 90%. Sausage product yields, in case of this emulsion application, were very high, product quality-satisfactory /41/. A similar effect is also achieved if, for emulsion preparation, the broth was used resulting from ham cooking, which contains enough products of collagen hydrolysis /19/.

Quite fine and stable direct emulsions are obtained at fat concentration within 10-40%. Concentrated emulsions are more convenient in use as they occupy a smaller volume, it is easier to adjust protein-fat-water proportions with them in sausage emulsions. Of no less importance is sufficiently strong binding of water and the dispersed phase in them. Such emulsion additions to the sausage mix increases, rather than decreases, strongly-bound water in the sausage emulsion /41/.

As for emulsion quantity added, it can be simply calculated on the basis of a desirable protein-fat proportion in the product. In any case, if to the sausage mix of uniformly-structured products is added the amount of 40%-emulsion, that provides fat-protein ratio 1:1 or over, it is still remains possible to add 10% snow to prevent sausage mix super-heating during its comminution in a cutter.

C o n c l u s i o n

Rational utilization of animal fats with a due account for their doses, processing methods, provision of the most optimum binding of fat, protein and water is an important problem of sausage technology. The food value of sausage products is determined with fat content and structure, with the spatial distribution and bonds of protein and fat components of sausage emulsions, with finished product structure. The highest quality of sausages is achieved at the optimum protein-fat-water proportions. Under-estimation of the fat component leads to wrong practical recommendations, in which the ultimate effect is related to the properties of the protein component only. Increasing fat content in sausage mixes changes the viscosity of the latter; fat acts as a plasticizing agent as the strength of the bonds, holding dispersed fat particles in the system, is comparatively small.

Product structure formation by protein, lipid and water components occurs in the process of comminution, post-stuffing holding and thermal processing.

The quality characteristics and the food value of the finished product are, to a great extent, determined with changes in the fat component during processing, and in particular, with the formation of fat emulsion. The available technological processing of fat in sausage production results in only partial fat emulsification. At the same time, it is desirable that the emulsifiable fat amount be as large as possible and the resulting emulsion be direct (this guarantees high palatability of the product) and stable, resistant to decomposition during heating. Emulsion stability is determined by the condition of proteins, in particular, of myosin, actin, globular proteins having a stabilizing effect; by pH; by phosphate, blood and milk proteins, etc. addition.

A much greater effect can be achieved when adding ready fat emulsions to sausage mixes. Such sausages are better digested, fat is evenly distributed in product structure, the water-binding capacity is increased, the finished product has better organoleptical qualities and higher yields.

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