Experimental determination of physico-chemical and disperse characteristics and thermal parameters of sheep tail fat

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Abstract. The article discusses the experimental determination of the level of salinity, melting temperature, dispersed composition of crushed sheep tail fat, its moisture content and analysis of the state of moisture in it, and presents the results of these studies. The information obtained is necessary because the approach recommended by the authors contributes to a longer storage of the final product. Systematization of the advantages and disadvantages of the known technologies of smoked sheep tail fat, will allow to compose a rational technological flow of the production of this product and also to determine the rational operating parameters of the implementation of its stages. The information presented in the article on the physicochemical and dispersed characteristics, as well as the thermophysical parameters of sheep tail fat is relevant. At present, researchers have increased their interest in extruded products with a developed structure, obtained on the basis of raw materials of animal origin, as a source of high-quality fats, as well as a basis for therapeutic and prophylactic nutrition products of various technological forms.

1. Introduction

Animal fats: beef and mutton have a regulating effect on blood lipids and the development of cardiovascular diseases. The use of by-products contributes to food security and the regulation of high and low density lipoproteins in the human body [1].

Studies of Bhatt RS, Soni L., Gadekar YP, Sahoo A., Sarkar S., Kumar D. [2, 3, 4, 5] showed that the high content and optimal ratio of PUFA, ω-6: ω-3 in sheep fat, especially in young lamb fat, makes this by-product promising, especially for production of functional products with desired properties.

Based on the above, we are working on the development of food products based on sheep tail fat.

In recent years, the interest of researchers in extruded products with a developed structure, obtained on the basis of raw materials of animal origin, has increased. First of all, as a source of high-quality fats, as well as a basis for products of therapeutic and prophylactic nutrition of various technological forms. One of the promising directions in this area is the expansion of the range of products with a developed structure, by changing their taste and aroma with natural smoky smoking, which provides an increase its storage [6].

Systematization of the advantages and disadvantages of the known technologies of smoked sheep tail fat, as well as the study and analysis of the complex of its target characteristics and thermal engineering parameters of the procedure for dehydration of granules with a protective coating is very
important. It allows to compose a rational technological flow of the production of this product and to determine the rational operating parameters of the implementation of its stages.

Based on preliminary staging testing of individual stages, a rational layout of the technological flow for the production of granulated smoked products from sheep tail fat is recommended is shown in Figure 1.

**Figure 1.** Rational layout of the technological flow for the production of granulated smoked products from sheep tail fat

The proposed technology provides for the operations of grinding, salting and dehydration. So, to assess the kinetics and efficiency of these processes, it is necessary to determine the level of salinity, melting temperature, dispersed composition of crushed sheep tail fat, its moisture content and analysis of the state of moisture in it.

The procedure for grinding of sheep tail fat is necessary to intensify mass transfer during the operation of smoking it. It will increase the contact surface area between product particles and smoking smoke and the porosity of the dispersed material. It should be noted that the porosity of the product is interrelated with the degree of its grinding and determines the intensity of mass transfer.

The procedure for salting of sheep tail fat is necessary for preserving the product and giving it a specific taste. It should be noted, that the salt concentration is not a variable parameter in the study, but is standardized for the industrial production. In addition, the salinity of the product determines not only its taste, but also the complex of its physicochemical characteristics, and for this reason, it also indirectly affects the intensity of mass transfer.
The saturation of sheep tail fat with smoking components has a relatively small effect on the complex of its thermophysical characteristics due to the fact that, unlike traditional cold or hot smoking of a product of animal origin. In our case, the drying procedure is not provided, because sheep tail fat contains a small amount of moisture, which is confirmed by the results of this study.

The recommended approach to obtaining pellets from sheep tail fat includes the operation of applying a protective coating, as well as drying it to form a surface edible packaging layer, which predetermines the development of a rational method of coating and dehydration without negative thermal effects, which predetermines the need for its melting point.

The problem of grinding and the production of minced semi-finished products from raw materials of animal origin in general is studied in the special literature [6, 7, 8, 9]. It should be noted, that in this studies there are no guidelines for determining the particle size of the processed raw materials. Only general theoretical provisions are given. The degree of dispersion is the main criterion for calculating the duration of the grinding process, is carried out depending on the kinematic and geometric characteristics of the machines, used also on the subjective assessments of experts. It is associated with the imperfection or complexity of experimental studies to determine the threshold values of the rheological properties of the final semi-finished product.

The ability of fat to emulsify and to assimilate it by the body, depends on its melting point, the easier it is emulsified with water and the higher its digestibility [10,11].

The melting point of fats depends on the nature of the fat, the body condition of the livestock, breed, age of the animal, and a number of other reasons. The more saturated glycerides in the fat, the more refractory the fat. The fat removed from the internal organs is richer in solid glycerides than subcutaneous fat. The fat of the same animal is the poorer in glycerides of unsaturated acids, the closer the corresponding parts, from which the fat is removed, lie to the gastrointestinal tract. Animals of warm climates have more solid fat than animals of temperate or cold countries [11,12,13].

For glycerides and their mixtures, the presence of double melting points is characteristic. The melted fat upon further heating by several degrees, solidifies again and then finally melts. Upon re-melting soon after solidification, the fats melt at a higher temperature. The normal melting point appears only after prolonged or deep cooling. These double melting points of glycerides are explained by polymorphism, which means that a substance of the same chemical composition can exist in a solid state in several forms or modifications [14]. The latter have different physical properties, in particular, different melting points.

On rapid cooling of glycerides and fatty acids, usually only an unstable or labile modification is precipitated, which has the lowest melting point. During long-term storage of such a glyceride in a crystallized state, the labile modification begins to transform into a stable one. While the duration of the transition depends not only on temperature, but also on the molecular weight of glycerides [12,15].

The aim of the study is to determine the level of salinity, melting point, dispersed composition of crushed sheep fat, its moisture content and to analyze of the state of moisture in it.

2. Methods
The object of the research was sheep tail fat, which surpasses other types of animal fats in its balance.

It is known that microscopic research methods are widely used in laboratory practice [16]. A wide variety of modern types of microscopes makes it possible to determine the size of particles with high accuracy to describe morphology and to study the structure.

At present, on the basis of electron microscopes it possible to determine the size and shape of particles, the elemental or phase composition, estimate the interplanar distance, detect crystal lattice defects, etc.

For pre-canning the product and giving it the necessary consumer properties, a procedure is provided for salting dispersed tail fat. The salt concentration is not a variable parameter, but is standardized by the technical specifications [17], in which the mass fraction of table salt in the finished product is not should exceed 3%.
There are different ways of salting bacon, but the fastest is the "wet" method, that is, in brine. A simple brine consists only of water and salt. Sugar, ascorbic acid, spices, etc. are also added to a complex brine. The salting of the object of research was carried out according to the method presented in the source [18] as follows.

Dispersed sheep tail fat was poured with water and boiled for 5-7 minutes. Then the water was drained and the fat was allowed to cool. Saline solution was prepared at the rate of 200 g of sodium chloride per liter of water at room temperature. Then prepared fat was placed in the saline solution prepared in this way at the rate of two liters of brine per kilogram of raw material. After placing the dispersed fat in the saline solution, it was pressed down by pressure and kept in brine for two days. After which this binary system was separated by draining excess brine under the action of gravity on mesh baking sheets.

As a result, a salted product was obtained, which was subjected to research to determine its salinity in the aspect of compliance with the normative document [17]. The salinity level was found by means of a conductometric salinometer, which allows to measure the electrical conductivity, determines the level of salinity of the test product, which compares favorably with the Mohr titration method [19].

The moisture content of the fat tail was determined using an AND MX-50 moisture meter using the heating method. This moisture meter is preferred for applications where resolution less than 0.01% and 0.001% is required. [20]. There is no difference in the results obtained by the Karl Fischer method and the heating and drying method, however, an AND MX-50 moisture meter has the best repeatability of results [20]. Its operation and maintenance are low-cost, which makes it possible to use these instruments by a wide range of users testing various types of samples.

The experimental determination of the moisture content in fat tail fat was carried out at a temperature of 105 °C, according to the recommendations given in the sources [21,22].

3. Results
The results of the studies carried out to determine the duration of the grinding process of sheep tail fat are presented in Table 1.

| Type of raw material | Grinding duration, sec | Conditional degree of grinding, m/m | Property of an object perceived by tactile sensation |
|----------------------|-------------------------|-----------------------------------|---------------------------------------------------|
| Sheep Tail Fat       | 3…4                    | ≈4                                | Coarse grinding                                   |
|                      | 5…6                    | ≈5                                | Coars grinding                                    |
|                      | 7…8                    | ≈7                                | Intermediate value                                |
|                      | 9…10                   | ≈10                               | Close to thin                                     |
|                      | 11…12                  | ≈40                               | Fine grinding                                     |

Figure 2 below shows micrographs of the research object after the procedure of its grinding.

![Figure 2. Micrographs of sheep tail fat.](image-url)
Judging by the micrographs, as a result of grinding, particles with a small size scatter are formed, which a priori predetermines a more uniform saturation of them with smoking components.

The results of the studies to determine the salinity level of dispersed fat tail fat are presented in Table 2. The results obtained showed their compliance with the established standards.

**Table 2.** The conditional degree of grinding lard, depending on its duration.

| Type of raw material | Number of experiment | Readings on the display of the device | Salinity level (salt concentration),% |
|----------------------|----------------------|---------------------------------------|--------------------------------------|
| Sheep Tail Fat       | 1                    | 0.21                                  | 2.1                                  |
|                      | 2                    | 0.22                                  | 2.2                                  |
|                      | 3                    | 0.20                                  | 2.0                                  |
|                      | 4                    | 0.22                                  | 2.2                                  |
|                      | 5                    | mean                                  | 2.1                                  |

4. Discussion

Considering that fats are a mixture of different glycerides with different melting points, their transition from solid to liquid does not occur immediately, so it is difficult to capture. The melting point of fats is not an exact constant. Fats also freeze not immediately, but gradually. First, the most refractory components pass into a solid state, which is expressed in the opacity of the mass, it becomes stronger and stronger until the entire mass solidifies. The end point of this continuous solidification is very difficult to determine [12, 13]. More characteristic is the temperature that remains unchanged for some time after the fat has solidified, or that maximum temperature that is reached during fat freezing due to the release of the latent heat of fusion. These temperatures are called the pour point of fats [12, 14, 15]. Analysis of the literature data showed that the melting point of fat (except for sheep tail fat) is in the range from 44 to 55 °C, and for sheep tail fat 33 to 44 °C; pour point 34 ... 45 °C, and for sheep tail fat - 32 ... 41 °C [8, 18].

The chemical composition of raw lamb fat depends on the species, breed, fatness and sex of the livestock [6, 8]. The average chemical composition of the fat of the first category of fatness is as follows: fat 87.88%, moisture 10.48%, protein 1.64% [11, 13]. The fat composition of sheep tail fat is characterized by a high content of oleic acid (41.4%) with an insignificant amount of other unsaturated fatty acids: linoleic (2.8%), hexadecene (1.2%), tetradecene (0.2%), etc.; of the saturated fatty acids, there are stearic (30.5%), arachidic (20.1%), palmitic (2.2%), lauric (0.6%) [13, 14, 23].

The melting and pouring points of rapidly cooled fats do not vary so much among it. The slower the temperature change, the more these points converge. [12]. Often, it is not the pour point of fat that is determined, but the pour point of fatty acids isolated from it (the so-called fat titer).

Experimental determination of the moisture content in sheep tail fat is necessary for the reason that during coating and drying there is an effect of moisture transfer from the fat to the coating, which obviously affects the drying kinetics of the biodegradable protective film. It is known a priori that the proportion of moisture in lipid products is small [12, 14, 15,19, 20, 21, 22, 23]. In engineering practice, in particular, when modeling the process of coating dehydration, it can be ignored. However, the data on its amount in sheep tail fat in literary sources are not unambiguous, therefore, to assess the feasibility of taking into account the moisture content for the selected object of study, it is reasonable to determine its moisture content.

On the basis of the study, a graphical dependence of humidity on the duration of the experiment was obtained (Fig. 3). As a result, the obtained moisture content of the investigated product is \( W = 7\% \).
Figure 3. Graph of the dependence of the moisture content of sheep tail fat on the duration of the experiment.

The increased moisture content reduces the nutritional value and stability of fat during storage and contributes to the development of hydrolytic processes. It is also indicating a violation of the technological mode of melting and settling of fat. In our case, the percentage of moisture in fat tail fat turned out to be lower than those values that can be seen from open sources [12, 14, 15, 19, 20, 21]. For example, 10.48% [22, 23] from which it follows that the result obtained.

Almost all the moisture in the test product is in a bound state, but it requires a confirmation. So, it is necessary to dehydrate the fat tail fat using the same moisture meter, and to build a drying rate curve, based on the results obtained. Since drying is a typical heat and mass transfer process, its kinetics will determine the form of moisture-material bond. As a result, on the basis of the research carried out, a graphical dependence of the change in the drying rate on the moisture content of the research object was obtained (Fig. 4, 5).

Figure 4. Kinetics of sheep tail fat drying rate.

The analysis of the obtained curve confirms that practically all the moisture in the investigated product is in a bound state and it is mainly a chemical bond (ionic and molecular). It should be noted that, although there is no sharp boundary between the individual forms of fluid bonding, the prevalence of one type of bonding over another is clearly observed (Fig. 5).
Figure 5. The initial section of the drying rate kinetics curve.

Thus, analyzing the kinetic curve of the dehydration rate, we come to the conclusion that sheep tail fat contains a certain proportion of moisture (7%), and given that the lipid and water fractions are mutually insoluble. So, we can conclude that moisture in the studied lipid product is present in a bound state. All this determines the absence of desorption shrinkage in the process of cold smoking in the investigated dispersed sheep tail fat and does not lead to a decrease in the mass of marketable products.

5. Conclusions

Thus, as a result of the research, the variation of the salinity level, the melting temperature, the dispersed composition of the crushed sheep fat tail fat and its moisture content were experimentally determined. The results obtained can be recommended for use in engineering practice.

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