Granulated goat milk sublimate and the experimental setup for its production

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Abstract. Prospects for the use of goat's milk (GM) as a food system are associated with the intensification of biological processes of its reproduction, as well as technologies for its processing and preservation. The purpose of the study is to substantiate the method of preserving goat's milk using an experimental spray freeze drying unit. The object of the study was the milk of goats of the Zaanen breed. The differential scanning calorimetry (DSC) method established a difference in the amount of binding energy of water fractions with dry matter in GM, which causes differences in energy consumption for GM dehydration at different stages of the drying process. The results were used to develop a drying method that makes it possible to carry out the processes of dehydration of goat lactation products under the gentlest conditions close to thermal conditions when producing these colloidal systems in the animal body. An experimental spray vacuum sublimation plant was used to produce granulated GM. Combining the structural elements of spray and freeze dryers allows balancing between the structural complexity of the device, its energy efficiency and the quality of the product.

1 Introduction

The spectrum of immunodeficiency conditions has been expanding in countries with different levels of economic development since the second half of the 20th century [1]. This is the reason for the formation of a large number of diseases. One of the important causes of this condition may be a deficiency of immunomodulating factors in nutrition, especially in the case of SARS-CoV-2 [2].

Goat lactation products are considered to be sources of immunomodulatory factors in nutrition [3, 4], including fermentation products such as kefir [5].

The world market for goat milk and its products is positioned as growing. Goat milk is a valuable source of protein and immunoglobulin, and the breeding of goats on an industrial scale makes a healthy diet accessible to the general population [6]. At the same time, the production of goat milk in many countries is of a pronounced seasonal nature, which necessitates the development of modern approaches and methods for maintaining quality indicators and consumer characteristics that are typical of native goat lactation products during storage and processing [7, 8].

So, the prospects for the use of goat's milk (GM) as a food system are associated with the intensification of biological processes of its reproduction, as well as technologies for its processing and preservation.

A promising way to preserve the native properties and biological activity of the components of food systems, products of applied biotechnology and the pharmaceutical industry is freeze drying [9-11], and the cryoprotective effect of pumpkin, fig and banana purees [12] just like the pumpkin powder [13] for probiotic microorganisms in fermented milk products has been proven during freeze drying. A comparative assessment of the effect of spray and freeze drying on the functional properties of food systems is the subject of research by a number of authors [14-16].

The advantages of vacuum freeze drying over spray drying have been established for dried camel milk [14], glycated with D-allulose and fructose soy protein isolates [15], beetroot processing products [16]. It should be noted that the research of scientists is aimed at developing methods for intensifying the processes of freeze-drying [17, 18]. For this purpose, additional physical effects are used, such as microvibration [17] and treatment with pulsed electronic fields [18]. However, the disadvantage is high initial costs, which limits the release of sublimated products for widespread everyday consumption.

To date, spray vacuum freeze drying is recognized as an emerging technology for the production of medicinal substances and free-flowing powders [19]. In this case, an important role is given to the study of various controlled parameters of the process of spray vacuum-freeze drying. However, in relation to heat-labile food systems such as lactation products of farm animals, the combined method of spray vacuum-freeze drying has not been implemented sufficiently. The purpose of the study is to substantiate the method of preserving goat's milk using an experimental spray freeze drying unit.

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2 Objects and methods

The objects of the study were goat milk of the Zaanen breed. Milk was fresh and used after morning and evening milking. Milk was received from a milking herd of goats in the village of Novaya Usman in Novousmansky district of the Voronezh region.

Studies of the chemical composition and physico-chemical parameters of raw materials and dehydrated products were carried out according to standard and generally accepted methods in research practice.

Raw goat milk was studied on a METTLER TOLEDO STARE TGA/SDTA 851e thermogravimetric and differential thermal analysis device (Switzerland).

The freeze-drying processes of goat's milk were studied using the installation, the scheme of which is shown in [8].

The fractional composition of moisture in goat lactation products was assessed in accordance with the recommendations [20]. The essence of the method for determining the fractional composition of moisture in materials consists in the following. Based on the results of derivatographic analysis, a graph of the dependence of the natural logarithm of the rate of dehydration of the sample on the reciprocal value of its absolute temperature is plotted. Break points are determined on the resulting graph, and the corresponding values of moisture loss and moisture content of the product sample are determined from the derivatogram [20].

3 Results and discussion

Raw goat milk had the following organoleptic characteristics: consistency (homogeneous liquid without sediment and flakes); taste and smell (clean, without foreign smells and flavors that were not characteristic of fresh natural milk); color (white to light cream). Sanitary and hygienic safety indicators of goat's milk corresponded to the requirements of TR CU 033/2013 «Technical regulations of the Customs Union. About the safety of milk and dairy products». The studied samples of goat milk had the following physical and chemical parameters. The mass fraction of fat was 3.6-4.0%; the mass fraction of protein was 3.1-3.3%; acidity was 18.0 °T; the purity group was I, density was 1031.0 kg/m^3; the mass fraction of dry fat-free substances (dry fat-free milk residue) was 12.2%.

Derivatogram of goat milk is shown in Figure 1. The results of processing the goat milk derivatogram according to the method [20] are shown in Figure 2. In the obtained graphs, the break points (the starting break point, point 1, point 2 and point 3) and the corresponding values of moisture loss were determined.

In view of this, in each graph, areas corresponding to the areas of removal of water fractions from the product were highlighted, and the moisture content values corresponding to the boundaries of the three water fractions were determined. Therefore, in these goat lactation products, three water fractions should be distinguished. The starting break point was 1; 1-2; 2-3, which differ in the value of the binding energy of moisture with the dry part of the sample. Quantitative data on the moisture content of each fraction are presented in the table.

Table. The fractional composition of water in goat's milk.

The water fraction number in goat's milk	The moisture content range of goat milk during water removal	The proportion of the water fraction in the total water content of goat's milk
1	13.65-11.6	15
2	11.6-0.11	84
3	0.11-0	1

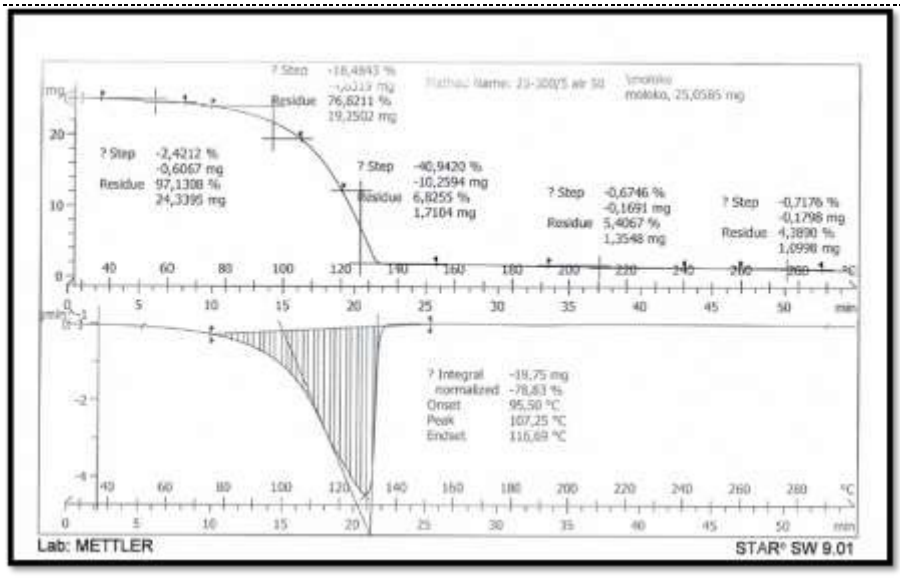

Figure 1. Goat milk derivatogram

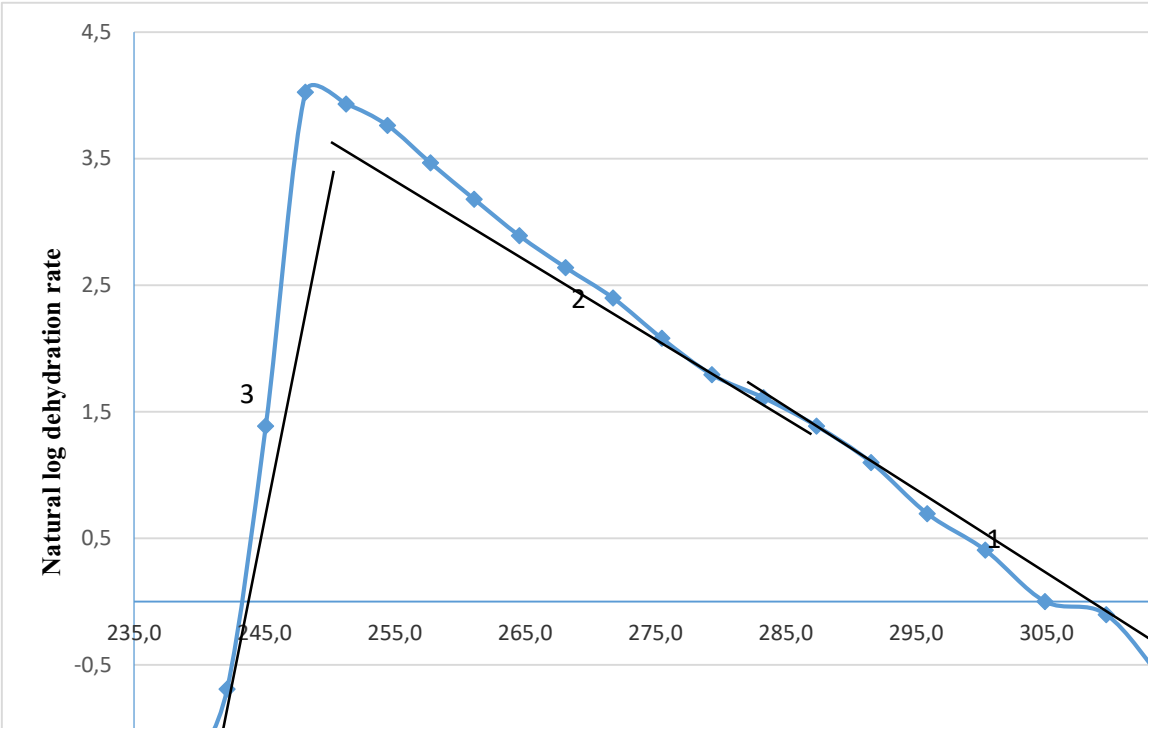

Figure 2. The graph of the dependence of the natural log of the dehydration rate on the inverse value of the absolute temperature of goat's milk

The results were used to develop a drying method that makes it possible to carry out the processes of dehydration of goat lactation products under the gentlest conditions, close to thermal conditions when producing these colloidal systems in the animal body.

The production of drinking goat milk includes the following technological operations:

- sampling raw milk and carrying out an examination of its physicochemical and organoleptic parameters;
- bringing the product to the required fat content by adding cream or skim milk to the milk;
- removing mechanical impurities and microorganisms using centrifugal cleaners or by filtration through mesh, gauze and flannel filters;
- heating the milk to the pasteurization temperature for a certain time to remove pathogenic microflora;
- cooling the milk to a temperature at which the development of microorganisms and oxidative processes is suspended.

However, to obtain freeze-dried products, it is sufficient to limit it to cold disinfection. When producing drinking goat milk, compared to cow's milk, there may be no homogenization, since the size of the fat globules in goat milk is significantly smaller and remains suspended in solution [8]. It should be noted that the production of dairy products from goat's milk does not require additional equipment compared to the processing of cow's milk.

Figure 3 shows a fundamental technical approach to combining the design features of vacuum-sublimation and spray dryers are illustrated by the design features of the installation.

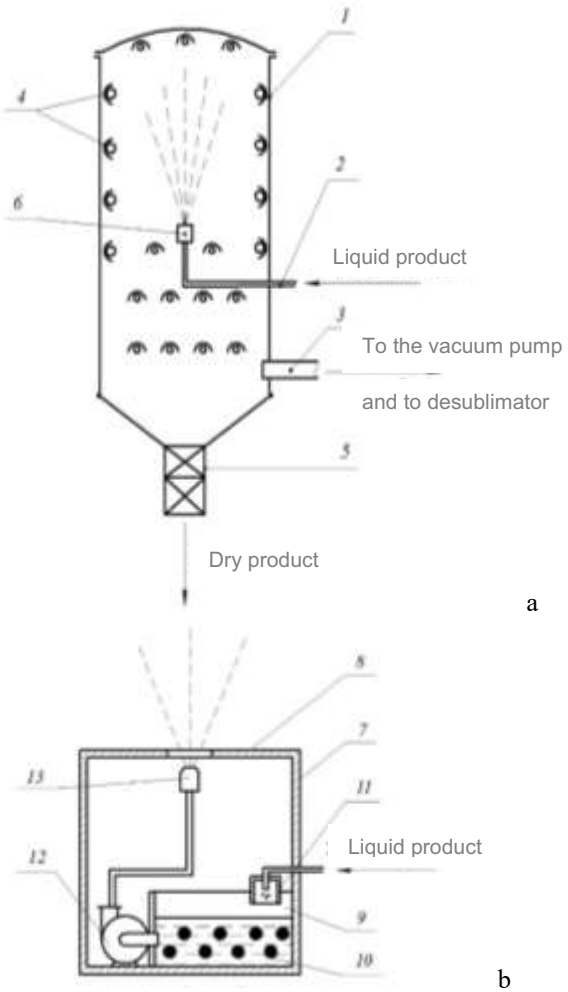

Figure 3. The sublimation spray dryer

As can be seen in Figure 3, the sublimation spray dryer for dewatering liquid products contains the camera (a) with the granulator (b). The sublimation spray dryer device has the following design features. 1 is the sublimation chamber; 2, 3 are nozzles; 4 is IR emitters; 5 is the sluice gate; 6 is the granulator; 7 is the evaporation chamber; 8 is the partition; 9 is the evaporation bath; 10 is heaters; 11 is fixing nozzles; 12 is the pump; 13 is the mechanical nozzle.

The unit is equipped with a granulator to increase the solubility of the product and improve its storage capacity.

The technology for the production of goat milk sublimate provides for the following sequence of operations: acceptance and preparation of raw materials →freezing the product →freeze-drying the product → granulation →packaging, labeling →storage.

When obtaining dry goat milk, the technological operations were carried out under the following conditions:

- primary purification from mechanical impurities by filtration through lavsan no later than 2 hours after milking;
- ultra-fine purification on a filter element made of food-grade polypropylene with a micropore size of 3 μm, at a pressure of 0.05 MPa, which made it possible to avoid pasteurization of milk;
- freezing at minus 40 °C and sublimation at a desublimator temperature of minus 60 °C for 5-6 hours.

The product has the following indicators (%): the mass fraction of protein is 28.5; fat is 30.5; carbohydrates are 35.0; ash is 2.5; the solubility index is 0.02 cm^3; acidity is 18 °T.

4 Conclusion

In order to increase the economic efficiency of freeze-drying, it is advisable to use a combination of various devices in order to combine their technological and operational functions and thereby to obtain more advanced equipment that combines the most useful elements of its prototypes. It is advisable to combine structural elements of spray and freeze dryers, combining their advantages, resulting in a balance between the structural complexity of the device, its energy efficiency and the quality of the finished product. The unit is equipped with a granulator to increase the solubility of the product and improve its storage capacity without loss of physico-chemical quality indicators, as well as to ensure the best preservation of the properties of the native product due to components with biological activity. The temperature of dehydration of goat milk, which is close to the temperatures of both its biosynthesis and absorption in the animal's body, made it possible to achieve the result.

Considering the economic and environmental advantages of developing goat farms compared to cattle farms, including higher milk yields per unit of feed, it is advisable to introduce a spray vacuum-sublimation unit into the technological cycles of processing goat lactation products in peasant farms. It is advisable to supplement vertically integrated schemes for the production and processing of goat lactation products at industrial agricultural enterprises of various capacities with equipment for the production of granulated sublimated goat milk.

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