Selection of effective technological parameters for vacuum drying of hard cheeses

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Abstract. The work is devoted to the study of the influence of such vacuum drying technological parameters as the layer thickness and the degree of product grinding on the process efficiency. Experiments on vacuum drying of hard cheeses have been carried out while selecting the above parameters. Their influence on the duration of the process, organoleptic assessment and mass fraction of moisture in dry products has been established. It was found that with an increase in the thickness of the product layer, the duration of dehydration increases, but this increases the productivity of the installation as a whole. There was calculated values of the product relative surface for various degrees of grinding and shape. The organoleptic assessment made it possible to establish that the best quality is characterized by cheeses dehydrated with a thickness from 10 to 30 mm. In this mode, the organoleptic score can reach 26 points. If the layer thickness increases up to 40 mm, the organoleptic score decreases to 25-24 points. The mass fraction of moisture in dry cheeses has been determined depending on the thickness of the drying layer, the shape of the product and the degree of grinding. It was found that it is advisable to dehydrate cheeses with the above grinding parameters, which provides a minimum drying time, high quality indicators of the product, minimum energy consumption, and reaching the moisture mass fraction no more than 7%.

1. Introduction
Vacuum drying is one of the most effective technologies for dehydration of food raw materials [1-7]. By the method of vacuum drying it is possible to obtain high quality products; moreover, in comparison with the traditional method - freezing, there is a significant advantage, such as a significant decrease in volume and, as a consequence, a reduction in the cost of transportation and storage of the product [8 - 14].

The kinetics of the vacuum drying process and the quality of the finished product are influenced by a number of technological parameters, including the shape and size of the product [15 - 17].
2. Results
The study is devoted to the selection of the effective degree of product grinding during the vacuum drying process. As for objects of the research there were selected hard cheeses of the following brands: "Sovetskiy", "Gollandskiy", "Kostromskoy" and "Poshekhonskiy". The thickness of the drying layer was selected; for this, the cheeses were crushed to a thickness of 10, 20, 30 and 40 mm before loading into the chamber.

Figure 1 shows graphs of temperatures changes in central layers of the product at different layer thicknesses.

![Figure 1. Temperature graphs for vacuum drying cheese at different layer thicknesses: a - "Sovetskiy"; b - "Gollandskiy "; c - "Kostromskoy"; d - "Poshekhonskiy"](image)
It was found that with an increase in the thickness of the product layer, the duration of the central layers reaching the required temperature increases as well. During dehydration of “Sovetskiy” cheese, the required temperature of 60 °C by the central layers is achieved with a layer thickness of 10 mm in 110 minutes; and with a layer thickness of 20 mm – in 190 minutes. In the case where the layer thickness was 30 mm, this time was 260 minutes, and with a layer thickness of 40 mm, it was 360 minutes.

When other cheeses are dehydrated, the temperature changes in the central layers are similar. With a layer thickness of 40 mm in the central layers of “Sovetskiy” cheese, the required temperature is reached in 360 minutes after the start of the drying process, of “Gollandskiy” cheese - after 250 minutes, and of “Poshekonskiy” - after 280 minutes. It should be noted that “Poshekonskiy” cheese warms up faster than the “Sovetskiy” cheese, since the installed heat flow density for it is 7.36 kW/m², and for “Sovetskiy” cheese it is 5.52 kW/m².

Figure 2 shows graphs of the dependence of the duration of cheeses’ vacuum drying on the thickness of the product layer and the degree of grinding.

![Graphs of the dependence of the vacuum drying duration for “Gollandskiy” cheese on the layer thickness and the degree of grinding:](image)

**Figure 2.** Graphs of the dependence of the vacuum drying duration for “Gollandskiy” cheese on the layer thickness and the degree of grinding:

- a - cubes in size: 1 - 6x6x6 mm; 2 - 10x10x10 mm; 3 - 15x15x15 mm;
- b - rectangles in size: 1 - 30x6x6 mm; 2 - 30x10x10 mm;
- c - granules with a diameter of 1 - 2 mm; 2 - 5 mm; 3 - 8 mm

It was found that with an increase in the layer thickness, the duration of cheese dehydration increases with all types of grinding.
To calculate the duration of the cheeses’ dehydration depending on the thickness of the drying layer, the shape and size of grinding, the equations shown in Figure 2 were developed. In the equations presented, \( x \) denotes the thickness of the layer.

Increasing the layer thickness not only prolongs the duration of the drying process, but also raises the productivity of the installation. For example, with a layer thickness of 10 mm, the product loading into the chamber is 5 kg, and the dehydration time is 190 minutes. With a layer thickness of 40 mm, the product load is 20 kg, and the process time is 450 minutes. With an increase in the duration of the process of 2.4 times, the productivity of the dry product increases 4 times. The efficiency of using the installation with a product layer thickness of 40 mm in comparison with a thickness of 10 mm increases 1.7 times.

However, it should be noted that the increase in the efficiency of using the drying unit by increasing the layer thickness is limited by the quality parameters of the dry product and the content of the mass fraction of moisture in it. It was found that for the same type of cheese with the same layer thickness, but different shapes and sizes of particles, the duration of dehydration is different.

The final choice of the investigated technological factors of the shape and size of the product should be based on the quality indicators of the dry product, the content of the moisture mass fraction and the specific heat consumption.

It was found that the highest organoleptic score (up to 26 points) was characteristic of cheeses dried with a thickness of 10 to 30 mm. With a product layer thickness of 40 mm, the organoleptic score is reduced to 25-24 points. With a layer thickness of more than 30 mm, the deterioration of the quality indicators of dry cheeses occurs due to uneven drying throughout the layer thickness and the presence of a sticky mass.

Table 1 shows data on the moisture mass fraction in dry cheeses, depending on the thickness of the drying layer, the shape and size of grinding.

| Layer thickness, mm | 10   | 20   | 30   | 40   |
|---------------------|------|------|------|------|
| Plates, mm          |      |      |      |      |
| 17a2a1              | 3.7  | 3.9  | 4.5  | 6.8  |
| 55a5a2              | 4.0  | 4.5  | 5.3  | 7.5  |
| 85a30a5             | 4.8  | 5.6  | 6.7  | 8.0  |
| Cubes, mm           |      |      |      |      |
| 6a6a6               | 4.2  | 4.5  | 5.0  | 7.1  |
| 10a10a10            | 4.9  | 5.7  | 6.3  | 8.5  |
| 15a15a15            | 5.5  | 6.8  | 7.7  | 8.5  |
| Rectangles, mm      |      |      |      |      |
| 30a5a6              | 4.5  | 4.5  | 5.6  | 7.5  |
| 30a10a10            | 5.0  | 5.7  | 7.0  | 8.0  |

The moisture mass fraction of no more than 7.0% was possessed by cheeses dehydrated with a layer thickness of no more than 30 mm. With a layer thickness of more than 40 mm, for almost all forms and sizes of grinding in a dry product, the mass fraction of moisture was over 7.0%. Figure 3 shows graphs of changes in the moisture mass fraction of “Kostromskoy” cheese, in the process of vacuum drying at different layer thicknesses.

If the layer thickness increases, not only the drying time increase, but the moisture content of the dry cheese grows as well. With a layer thickness of 10 mm, the mass fraction of moisture was 4.2%; at 20, 30 and 40 mm - 4.5%; 5.0% and 7.1% respectively. An increase in the mass fraction of moisture in dry products with an increase in the layer thickness occurs due to a decrease in the rate of moisture removal and the intensity of heating of the central layers. With an increase in the thickness of the product layer from 10 to 20 mm, the drying time increases by 20–30%, and the mass fraction of moisture by 0.3–0.4%. In the case when the thickness of the drying layer increases from 30 to 40 mm, the drying time increases by 27–46%, and the mass fraction of moisture - by 2.1–2.3%.
There was revealed inexpediency of the cheeses dehydration with a drying layer thickness of more than 30 mm due to an increase in the duration of dehydration process, a decrease in the quality of the product and an increased content of the mass fraction of moisture in cheeses, as well as increased unit heat consumption.

3. Conclusion
Thus, for vacuum drying hard cheeses, the recommended technological parameters are:
- layer thickness from 10 to 30 mm;
- shapes and sizes: plates - 17x2x1, 55x5x2 mm; cubes - 6x6x6, 10x10x10 mm; rectangles - 30x6x6, 30x10x10 mm.

With the above parameters, the minimum duration of the drying process is observed, dry cheeses have high organoleptic characteristics, the mass fraction of moisture in the product is no more than 7.0%, and the specific heat consumption is minimal.

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