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DETERMINING THE INFLUENCE OF EQUIPMENT USED IN MODERN COTTAGE CHEESE PRODUCTION LINES ON THE QUANTITATIVE AND DISPERSED COMPOSITION OF CHEESE DUST

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This study investigated a change in the quantitative content and particle size distribution of curd dust during the production of cottage cheese with fat mass fractions of 0.2%, 5%, and 9%.

Modern cottage cheese production lines are characterized by a high level of mechanization of technological processes, which enables high productivity. However, mechanical impact on curd grains leads to their destruction and the formation of curd dust, the particles of which remain in the whey after its separation.

Losses of raw material in the form of curd dust affect the production cost of finished products, complicate further whey processing, and increase its environmental impact.

Changes in the curd dust content and its particle size distribution in whey have been investigated at different stages of production, from cutting and stirring the curd coagulum in the curd-making vat to whey separation on a belt conveyor.

The final average content of curd dust in the whey obtained during cottage cheese production was determined to be 4.78 kg/m3.

It was established that, on average, 25% of curd dust is formed in the curd-making vat. The maximum amount of curd dust (62%) is formed during the transportation of curd grains from the curd-making vat to the heat exchanger. In the heat exchanger, 13% of curd dust is formed. The formation of curd dust in the rotary lobe pump is explained by the significant mechanical impact on curd grains in this equipment.

To reduce the level of curd dust formation, heat exchangers with minimal hydraulic resistance should be used for cooling the curd grains. This allows the use of pumps with gentler operating characteristics (compared to rotary lobe pumps) for transporting curd grains from the curd-making vat to the heat exchanger. These measures could be applied in practice to reduce raw material losses during cottage cheese production on modern mechanized production lines

Keywords: cottage cheese production, curd dust content, particle size distribution of curd dust

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1. Introduction

Sustainable development of food production enterprises involves a whole range of measures that ensure economic efficiency, environmental safety, and social responsibility. Therefore, under modern conditions, the priority of food producers should be not only the production of the maximum number of competitive products but also taking into account the long-term interests of society and the environment. It is obvious that all these aspects are interconnected and, in many cases, can be solved comprehensively, especially since the vast majority of them are directly affected by the machine-hardware implementation of production.

As for ensuring the sustainable development of fermented milk cheese production, the machine-hardware implementation for this product will primarily depend on the fermentation technique – rennet or acid.

Production using traditional technology with the rennet fermentation technique using horizontal vats is characterized by low mechanization of technological processes, high energy consumption, and low sanitation.

The designed modern lines are based on the acid production technique. This allows for the mechanization of a number of technological processes and a significant increase in the level of sanitation. However, this approach is not without its drawbacks: the downside of a high level of mechanization is increased energy consumption, and significant mechanical impact on the cheese grain is accompanied by the transition of part of the protein into whey and its loss. Losses of raw materials in the form of curd dust affect the cost of finished products and complicate further processing of whey. And in cases where enterprises do not process whey, but drain it into drains, the high content of curd dust significantly increases its polluting effect on the environment.

Thus, reducing losses of raw materials in the form of curd dust is an urgent task, resolving which will not only reduce the cost of finished products but also facilitate the processing of whey and increase the environmental friendliness of production.

2. Literature review and problem statement

About 180–190 million tons of whey are produced annually in the world [1]. This is due to the ratio between the mass of the product and the mass of whey, the production of which accompanies the production of this product, which is on average 1 to 7. In [2], the polluting effect of whey is noted, which is largely due to the content of organic substances in it. However, determining the content of these substances in whey was not within the scope of interests of the authors of that study.

As is known, whey contains a large proportion of useful components of milk, which makes it a valuable secondary product. In [3], the amino acid composition of whey and products in the production process of which it is obtained was compared. The effect of various rennet enzymes on the amino acid composition of whey was studied. It was demonstrated that whey obtained in the production of fermented milk cheese remains rich in essential amino acids. It is noted that whey contains a significant part of the drinking nutrients of milk: lactose, soluble (whey) proteins, minerals (ash), fats, as well as vitamins and bioactive peptides. In [4], data are provided according to which the main part of the dry matter of whey, from 70 to 75%, is lactose. At the same time, since the interest of the authors of these publications [3, 4] was focused exclusively on the soluble components of whey, they do not have data on the content of dispersed protein particles in whey – curd dust.

The authors of [5] provide data on the content of curd dust in whey obtained during the production of fermented milk cheese in the USA. There are also studies on the content of curd dust in the production of fermented milk cheese at lines using cheese vats [6], according to which the content of curd dust in whey is 3.12 kg/m^3. These papers discuss raw material losses in the form of curd dust but do not consider the process parameters on which these losses depend. It is obvious that the authors' task was to provide a general assessment of the level of losses for existing production.

In study [7], the granulometric composition of curd dust was determined in the production of fermented milk cheese using cheese vats. The authors draw attention to the fact that the bulk of curd dust is concentrated in particles whose sizes allow them to be separated by conventional filtration. Based on the results of the study, methods for purifying whey were proposed. At the same time, the study did not provide for the determination of changes in the content of curd dust and its dispersed composition during the production process of the product, which would make it possible to propose measures to prevent the formation of curd dust.

In [8], using the example of Idiazabal cheese production, the relationship between production conditions and protein losses with whey was demonstrated. The authors found that increased fat and protein losses are observed when cutting a cheese curd with excessive hardness in combination with high cutting and heating intensity. However, these data were obtained during cheese production at small cheese factories with minimal mechanization of production processes. Therefore, they cannot be used to reduce curd dust losses during the production of fermented milk cheese on modern mechanized lines.

There are also studies that demonstrate the relationship between milk quality and protein losses with whey in the form of curd dust [9]. Milk quality was assessed by parameters such as protein and fat content, and coagulation properties of milk. The results prove that the use of higher quality milk, along with other advantages, also guarantees lower losses of dispersed protein. However, the authors note that milk quality depends largely on seasonality and, therefore, is a parameter that is poorly regulated. Thus, the data obtained state losses but cannot be used to reduce these losses.

A number of studies prove that such parameters of cheese makers' operation as the degree of cutting, mixing speed, processing duration and temperature affect the content of curd dust in whey. Thus, in [10] it was established that a decrease in the intensity of cutting the curd contributes to the formation of curd dust; an increase in the mixing speed of the mixture has a similar effect. Minimal destruction of cheese grains occurs under moderate cutting modes. According to the results reported in [11], early cutting of the curd and a higher process temperature also lead to an increase in the content of curd dust in whey. In addition, it was established that a high calcium content makes the curd excessively hard and brittle, which increases fragility. On the contrary, an insufficient calcium content contributes to the formation of a soft curd, which is easily torn during processing. The authors of both papers [10, 11] focused only on the processes occurring in the cheese maker but there are no research results that would prove that the formation of curd dust occurs exclusively in this apparatus. The lack of interest of researchers in the formation of curd dust in other devices is explained by the fact that until now it was believed that the main part of curd dust is formed precisely during the processing of the curd in the cheese maker. It should be noted that this statement is true in the production of fermented milk cheese on lines that involve the use of cheese vats and are characterized by a low level of mechanization. However, there are reasons to believe that when using modern lines, where the mechanical impact on the cheese grain is not limited to the cheese maker, the situation may be different.

Thus, available papers focus either on the total losses of curd dust in the production of different types of cheese or on the dependence of these losses on the mode of processing the curd in the cheese maker. However, it is obvious that the formation of curd dust occurs not only in the cheese maker but also in other equipment of the line where the mechanical impact on the curd takes place. In particular, it can be assumed that the destruction of cheese grains and the formation of curd dust will occur in pumps for transporting cheese grain-whey suspension, in heat exchangers for cooling cheese grains, etc. At the same time, the influence of the equipment used in the production of fermented milk cheese on the formation of curd dust remains unstudied.

This allows us to argue that it is advisable to conduct a study aimed at determining the influence of various devices in the fermented milk cheese production line on the formation of curd dust.

3. The aim and objectives of the study

The aim of our research is to determine the influence of individual devices in the fermented milk cheese production line on the formation of curd dust. This could make it possible to devise measures to prevent the formation of curd dust and reduce raw material losses in the production of fermented milk cheese.

To achieve the goal, the following tasks must be solved:

– to investigate the content of curd dust in whey at the outlet of individual devices of the line;

– to investigate the particle size composition of curd dust at different stages of production.

4. The study materials and methods

4. 1. The object and hypothesis of the study

The object of our study was the quantitative and particle size composition of curd dust in whey during the technological process in the devices of the fermented milk cheese production line with a mass fraction of fat of 0.2%, 5%, and 9%.

The principal hypothesis assumes that the mechanical impact on the cheese grain, which takes place in the devices of the fermented milk cheese production line, is a determining factor in the formation of the quantitative and particle size composition of curd dust.

The assumptions adopted in the work:

– curd dust was considered to be dispersed particles of protein nature, which are formed as a result of the destruction of cheese grain at different stages of production and which, due to their small size (compared to the size of cheese grain), remain in the whey during separation;

– the physical and mechanical properties of cheese grain (strength, brittleness, plasticity) within one experiment were considered constant and determined by the mass fraction of fat in the product;

– the quantitative and particle size composition of curd dust, determined in whey, was considered a representative indicator of the intensity of cheese grain destruction in the corresponding line apparatus.

The simplifications accepted in the work:

– the processes of deformation and destruction of cheese grains were considered without taking into account microstructural changes in the protein matrix, using integral indicators of curd dust formation;

– hydrodynamic processes in the pump and tubular heat exchanger were not modeled in detail; their influence was estimated indirectly through changes in the quantitative and particle size composition of curd dust;

– the processes of redeposition, aggregation, or coalescence of curd dust particles in whey were not taken into account, except in cases related to the methodology for determining the particle size composition;

– the influence of the filtering properties of the equipment (perforated drum, belt conveyor) was considered only from the point of view of changes in the content of curd dust in the removed whey, without analyzing the mechanisms of particle retention;

– the assessment of the particle size composition of curd dust was carried out taking into account the possible error associated with the adhesion of particles due to their adhesive properties, without introducing correction factors.

4. 2. Sampling methodology

The studies used samples consisting of whey and suspended particles of curd dust. Whey was considered a secondary product of the production of fermented milk cheese, containing curd dust. Samples were taken during the production of fermented milk cheese on a mechanized line in accordance with DSTU 4554: 2006 “Fermented milk cheese. Technical conditions”. The places of whey sampling are shown in Fig. 1.

Features of whey sample selection at different points of the fermented milk cheese production line are given in Table 1.

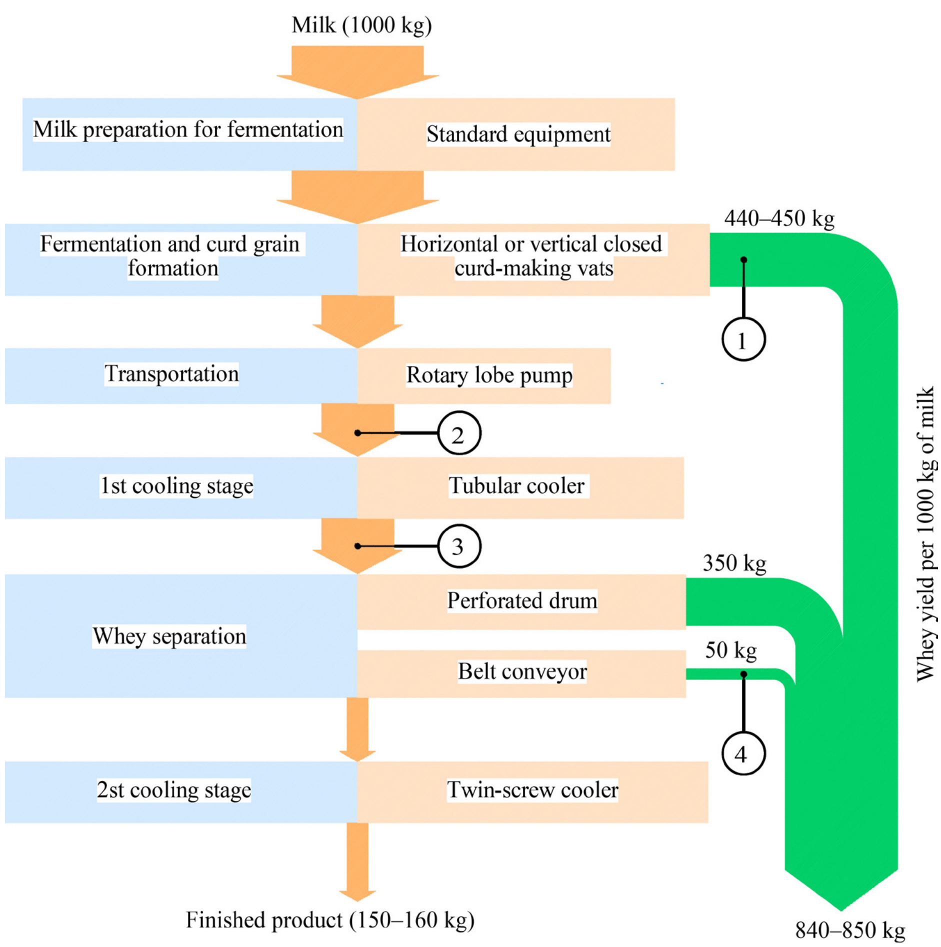

Fig. 1. Scheme of the fermented milk cheese production line indicating the locations of whey sampling: 1 – at the whey outlet from the cheese maker; 2 – at the outlet from the cam pump; 3 – at the outlet from the tubular cooler; 4 – at the outlet from the belt conveyor

Table 1

Features of whey sampling

No. of entry	Sampling location	Methodology for whey sampling
1	At the exit of the whey from the cheese-making vat	During the process of draining the whey, 1000 ml of whey was taken from the cheese-making vat every 10 minutes
2	At the outlet of the claw pump	Every 20 minutes, 1500 ml of curd grain-whey suspension was taken and filtered through a filter surface with a hole size of 1.0 mm, in order to separate the curd grain
3	At the outlet of the tubular cooler	
4	At the exit of the belt conveyor	During the process of draining the whey, 1000 ml of whey was taken from the belt conveyor every 10 minutes

Each of the selected samples was poured into one of four containers, which corresponded to the place of sampling of a given sample.

In these containers, the whey was settled for 2.5 hours in order to precipitate curd dust particles (the duration of precipitation was determined based on the sedimentation rate of curd dust particles with a size of 0.1 mm). Then, part of the clarified whey was removed from the containers using a hose, which was placed at a height of 50 mm from the upper edge of the sediment layer. Thus, sediment and a certain amount of whey remained in the containers, which were stirred and divided into 5 parts.

4. 3. Methodology for determining the content of curd dust in whey

Each of the 5 parts of whey was filtered through preweighed filter paper. After the filtration process was completed, the filter paper was dried in a drying chamber, and the mass of the dry residue was determined according to DSTU 7337:2013 (ISO 5537). The obtained values of the mass of the dry residue were summed and divided by the initial volume of whey in the container (before removing part of the clarified whey). This experiment was repeated five times. This methodology allowed us to significantly reduce the time and increase the accuracy of the experiments, since the volume of the selected whey in each of the four containers was more than 10 liters.

4. 4. Methodology for studying the particle size composition of curd dust

The methodology was based on the sieve analysis method. 5 sieves with different hole sizes D were used: 0.1; 0.25; 0.5; 0.75; 1.0. The mass of each sieve was previously determined. Then, each of the 5 portions of whey was passed through a sieve with a certain hole size. The mass of particles remaining on each sieve was determined by weighing the sieve with the particles present on it and subtracting the mass of the sieve itself. The mass of particles remaining in the whey after filtering it through a sieve with the smallest holes was determined by filtering the whey through filter paper. As a result, the mass of six portions of curd dust was obtained. Then, the mass of curd dust fractions was determined using the following expressions:

$$G_1 = m_1; \quad (1)$$

$$G_2 = m_2 - m_3; \quad (2)$$

$$G_3 = m_3 - (m_4 + G_2); \quad (3)$$

$$G_4 = m_4 - \left(m_5 + \sum_{i=2}^{n-3} G_i \right); \quad (4)$$

$$G_5 = m_5 - \left(m_6 + \sum_{i=2}^{n-2} G_i \right); \quad (5)$$

$$G_6 = m_6 - \sum_{i=2}^{n-1} G_i, \quad (6)$$

where m_1 is the mass of particles remaining on the filter paper, kg;

$m_2 \ldots m_6$ is the mass of particles remaining on the corresponding sieve, kg;

n is the number of fractional classes, $n = 6$ (5 sieves and 1 filter paper);

G_i is the mass of the i-th portion of curd dust, kg;

Thus, the masses of fractions with the following sizes were obtained:

– G_1 – less than 0.1 mm;
– G_2 – from 0.1 to 0.25 mm;
– G_3 – from 0.25 to 0.5 mm;
– G_4 – from 0.5 to 0.75 mm;
– G_5 – from 0.75 to 0.1 mm;
– G_6 – over 1.0 mm.

The mass fraction of each curd dust fraction was determined from the following formula

$$g_i = \frac{G_i}{\sum_{i=1}^{n} G_i} \cdot 100\%, \quad (7)$$

where g_i – mass fraction of the cheese dust fraction, %;

$\sum_{i=1}^{n} G_i$ – total mass of all fractions of cheese dust, kg.

4. 5. Methods for statistical data processing

Statistical processing of the results of experimental studies of the content and particle size composition of curd dust in whey was carried out in order to assess the reproducibility of measurements, identify patterns of changes in indicators at different stages of the technological process, and determine the reliability of the results.

All experimental measurements were performed at least three times. For each stage of production, the arithmetic mean value of the indicators, the standard deviation, and the coefficient of variation were determined, which allowed us to assess the variance of experimental data and the stability of the curd dust formation process.

An assessment of the statistical significance of the differences between the average values of the curd dust content at individual stages of production was carried out using the Student's test. In the case of comparing more than two samples, a one-way analysis of variance was used.

To analyze the particle size composition of curd dust, statistical characteristics of the particle size distribution were used: the average particle diameter and the proportion of fractions in the specified size intervals. The construction of distribution histograms and determination of distribution parameters were carried out using standard methods of variational statistics.

5. Results of investigating the content and particle size composition of curd dust at different stages of fermented milk cheese production

5.1. Results of investigating the content of curd dust in whey at the outlet of individual devices of the line

Our data on the content of curd dust in whey at different stages of production are represented in the form of a diagram in Fig. 2. According to these data, the content of curd dust in whey at the outlet of the cheese-making vat is on average 1.1 kg/m^3. The passage of the cheese grain-whey suspension through a cam pump and a tubular cooler is accompanied by an increase in the content of curd dust in whey to an average of 8.93 kg/m^3. At the same time, it was found that the content of curd dust in whey at the outlet of the belt conveyor significantly decreases and ranges from 2.8 to 5.3 kg/m^3.

As a result of determining the difference in the content of curd dust at the inlet and outlet of the corresponding equipment, the contribution of each equipment to the formation of curd dust was obtained (Fig. 3). Due to the decrease in the content of curd dust at the outlet of the conveyor, this equipment is not shown in Fig. 3.

Taking into account the different volume of whey, which is selected on separate devices of the line, the total content of curd dust in whey was determined (Fig. 4).

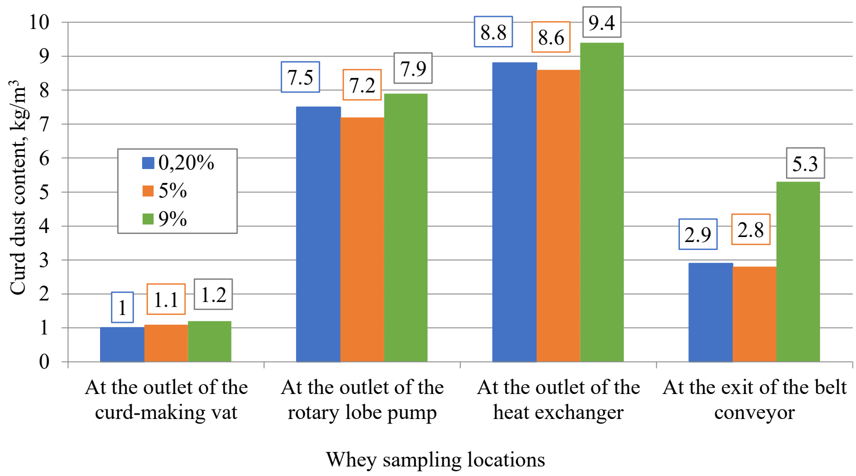

Fig. 2. Curd dust content in whey at the outlet of the equipment in the fermented milk cheese production line (for a product with a fat content of 0.2%, 5%, and 9%)

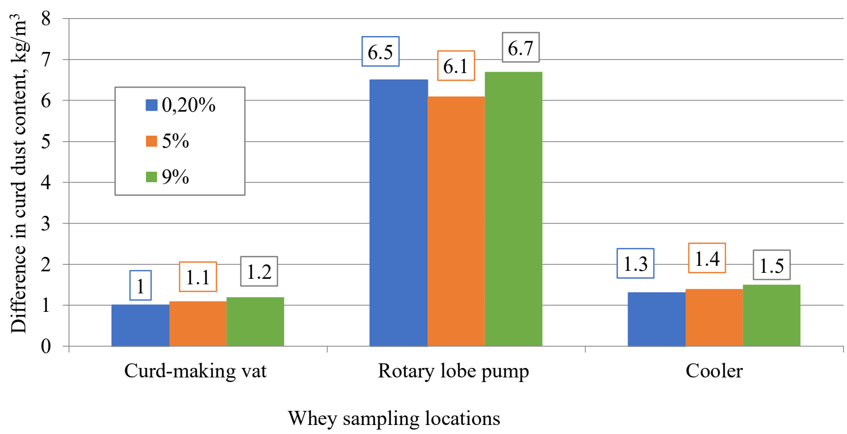

Fig. 3. The difference in the content of curd dust at the inlet and outlet of the corresponding equipment

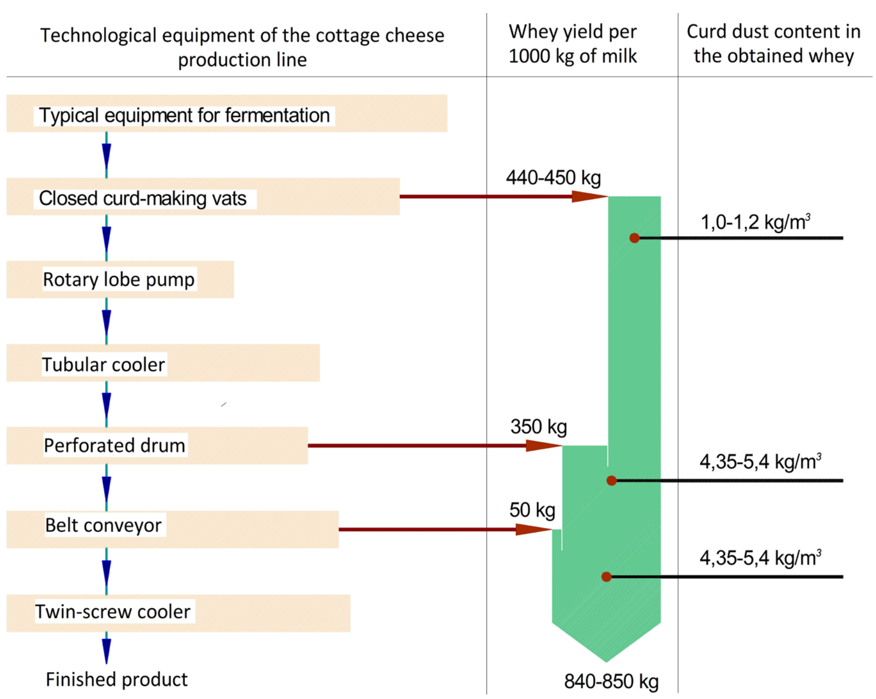

Fig. 4. Change in the content of curd dust in the total volume of whey separated at all stages of production

It was established that the final content of curd dust in whey, allocated at all stages of production, is from 4.26 to 5.3 kg/m^3 depending on the fat content of the product. Hereafter, the average value of the final content of curd dust in whey is used – 4.78 kg/m^3. Taking into account that whey is obtained 5.7 times more than the main product, it was determined that when producing 1000 kg of cheese, 27.3 kg of product turns into curd dust.

The data obtained show that during the cutting of the coagulum and stirring of cheese grains, an average of 1.1 kg is formed per 1 m^3 of whey. Considering that the average final content of curd dust in whey is 4.78 kg/m^3, it was determined that about 25% (Fig. 5) of the total amount of curd dust is formed in the cheese-making vat.

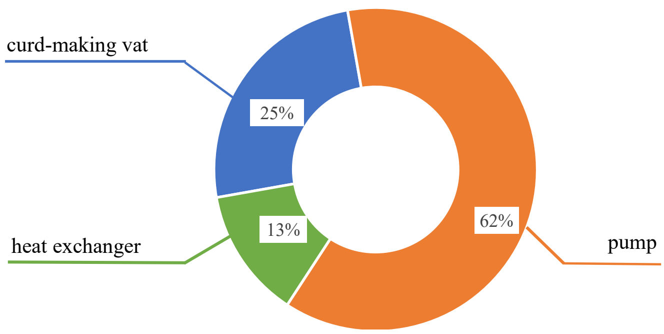

Fig. 5. The proportion of curd dust (% of its total amount) formed on individual line devices (determined as the average value of data obtained during the production of products with a fat content of 0.2%, 5%, and 9%)

The maximum amount of curd dust is formed when transporting cheese grains with whey using a cam pump – 2.96 kg/m^3. This is 62% of the total mass of curd dust formed during the production of fermented milk cheese.

During the cooling process of cheese grains in a tubular heat exchanger, 0.62 kg/m^3 of curd dust, or 13% of its total amount, is formed.

5. 2. Particle size composition of curd dust at differd ent stages of fermented milk cheese production

According to the results of our study on the particle size composition, the whey obtained at the outlet of the cheese-making vat is characterized by a relatively small size of curd dust particles (Fig. 6). Thus, in the production of a product with a fat content of 9%, particles with a size of less than 0.25 mm make up 48% (the sum of fractions with sizes < 0.1 and 0.1–0.25) of their total mass. For a product with a fat content of 5%, the proportion of curd dust with particle sizes less than 0.25 mm is 55%, and for a product with a fat content of 9% – 64% of the total mass.

As the suspension passes through the cam pump, the number of particles with relatively large sizes increases (Fig. 7). Thus, at the pump outlet, particles larger than 0.5 mm in size account for from 20% (at a product fat content of 0.2%) to 39% (at a fat content of 9%) of the total mass of curd dust.

When the cheese mass moves through the cooler channels, the formation of curd dust particles of various sizes is observed, as evidenced by the diagram of the granulometric composition of curd dust at the outlet of the heat exchanger (Fig. 8). According to it, the distribution of particles by fractions is close to a similar distribution at the outlet of the cam pump.

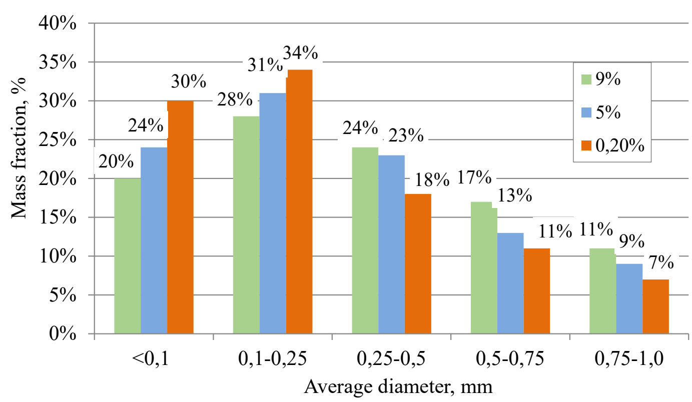

Fig. 6. Particle size composition of curd dust in whey at the outlet of the cheese-making vat for a product with a fat content of 0.2%, 5%, and 9%

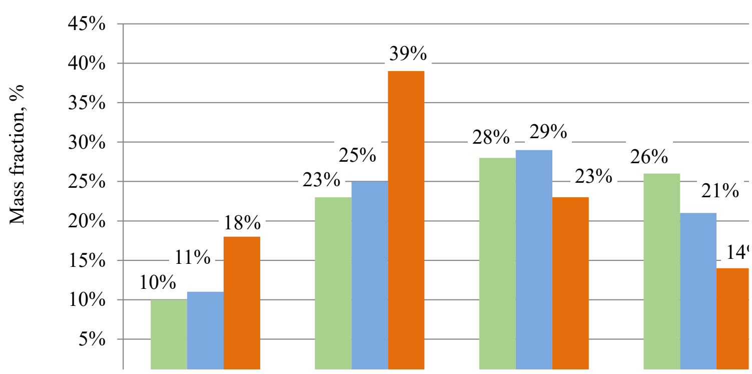

Fig. 7. Particle size composition of curd dust in whey at the outlet of the cam pump during the production of a product with a fat content of 0.2%, 5%, and 9%

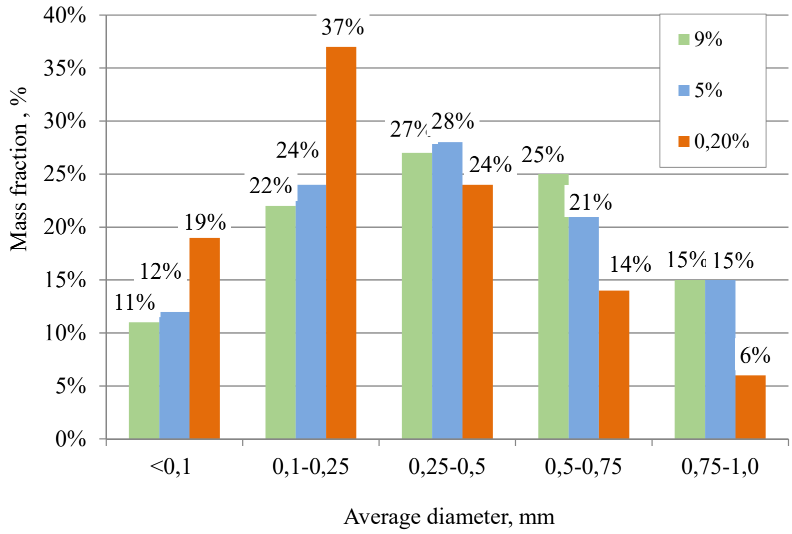

Fig. 8. Particle size composition of curd dust in whey at the outlet of the heat exchanger during the production of a product with a fat content of 0.2%, 5%, and 9%

At all stages of production, there is a relationship between the fat content of the product and the size of the curd dust particles – the smallest particles are formed when producing a product with a fat content of 0.2%, and the largest – respectively, when producing a product with a fat content of 9%.

6. Study on the content and particle size composition of curd dust in whey: discussion and results

The increase in the content of curd dust observed in such line devices as the cheese-making vat, cam pump, and heat exchanger (Fig. 2) is explained by the mechanical impact on the cheese grain that occurs in this equipment. At the same time, the rapid decrease in the content of curd dust in the whey separated on the conveyor (Fig. 3) is due to the filtering properties of the belt. Thus, the whey discharged at this stage is partially purified from curd dust.

Unlike [10, 11], which states that the formation of curd dust occurs in the cheese-making vat, it was found that this process also occurs in other line devices (Fig. 2–4).

This became possible due to the fact that these studies provided for the determination of the content of curd dust at the outlet of various devices in the technological line. The fact that in the production of cheese, fermented milk whey is discharged at three stages of the technological process was also taken into account. And also, that the volumes of whey removed at different stages (and the content of curd dust) are different.

Based on the data obtained (Fig. 2–5), it can be stated that the formation of curd dust occurs during such processes as cutting and mixing of cheese grains in the cheese-making vat, transportation of the suspension using a cam pump, and cooling in a tubular heat exchanger. Destruction of cheese grains and formation of curd dust during whey separation on a perforated drum and belt conveyor are not observed.

The fact that the maximum amount of curd dust (62%) is formed when transporting cheese grains with whey using a cam pump (Fig. 5) indicates a significant mechanical impact in this equipment. At the same time, cam pumps are widely used for transporting cheese grains. The reason for this is the positioning of these pumps, in particular by their manufacturers, as those characterized by a soft effect on the object of transportation. However, it is quite obvious that the impact of the pump's working elements on the product depends not only on its design and operating parameters – the properties of the product also matter. It can be assumed that cam pumps are indeed distinguished by a rather soft effect, but not on all products. So, there is no doubt that they are well suited for transporting suspensions whose dispersed phase is, for example, fruits or their particles, which are characterized by significant elasticity and resilience. At the same time, cheese grains are devoid of the aforementioned properties, and therefore even with insignificant mechanical action, its damage and destruction will occur. In this regard, the use of a cam pump for transporting cheese grain is accompanied by significant losses of raw materials.

At the same time, the use of a pump in the line is justified by the need to generate sufficient pressure for the suspension to pass through the tubular heat exchanger, that is, to overcome its hydraulic resistance. In turn, the high hydraulic resistance of the heat exchanger, which is associated with the repeated change in the direction of movement of the suspension in its channels, is also the cause of the destruction of cheese grain in the heat exchanger.

Thus, a promising direction for reducing the level of cheese grain destruction (and the formation of curd dust) in the production of fermented milk cheese is the use of heat exchangers with minimal hydraulic resistance. As a result, there will be no need to create high-pressure suspensions. Under such conditions, pumps with less mechanical action on the dispersed phase can be used to transport cheese grain with whey. Also, the use of heat exchangers with minimal hydraulic resistance will prevent the formation of curd dust in the heat exchanger itself.

In contrast to [5], in which it was established that the content of curd dust in whey during the production of the product on lines using cheese vats is 3.12 kg/m^3, we obtained significantly higher values – 4.78 kg/m^3. Therefore, it can be argued that the production of fermented milk cheese on modern mechanized lines is accompanied by the formation of a larger amount of curd dust compared to production on lines that include cheese vats.

The results of our study on the particle size composition of curd dust showed that its main part is concentrated in particles with a size of less than 0.5 mm (Fig. 6–8). Thus, the total share of curd dust fractions with an average size of less than 0.5 mm, i.e., the sum of the fractions with sizes <0.1 mm, 1.1–0.25 mm, and 0.25–0.5 mm, is over 60%.

This result contradicts the data reported in [6], according to which about 88% of the total mass of curd dust is accounted for by particles larger than 0.5 mm. However, it is obvious that the reason for the difference is that in [6] the studies were conducted in the production of fermented milk cheese using different equipment – open cheese vats. That is, the production of the product on modern mechanized lines is accompanied by the formation of curd dust of a smaller size than in production using open cheese vats. This is probably explained by the significant mechanical impact that, when using modern mechanized lines, acts not only on the cheese grain but also on the curd dust, which, together with the whey, sequentially passes through the line devices, which leads to its destruction.

The dependence of the average size of curd dust particles on the fat content of the main product (Fig. 6–8) is explained by the fact that the fat content in the cheese grain increases its plastic properties. Therefore, cheese grain with a lower fat content is more fragile than that in which the fat content is higher. As a result, when breaking cheese grains with a higher fat content, a smaller number of curd dust particles is formed than when breaking cheese grains with a lower fat content.

Analysis of the particle size composition of curd dust (Fig. 6–8) revealed that it is advisable to carry out whey purification in stages using different techniques. At the first stage, larger curd dust particles should be isolated by filtration through a perforated surface [12]. At the second stage, separation or centrifugation can be used to purify whey.

It should be noted that the data obtained in the work are adequate only for the process of production of fermented milk cheese on modern mechanized lines, which include vertical closed cheese-making vats, a three-cam pump, a tubular heat exchanger, a perforated drum, and a belt conveyor.

It is also necessary to note a certain drawback of this study – an error in determining the size and particle size composition of curd dust, which is caused by the sticking of its particles due to strong adhesive properties. Thus, a certain number of curd dust particles may have slightly smaller sizes compared to those that were obtained. On the other hand, the noted sticking (enlargement of sizes) of particles will also occur during their separation from whey under production conditions. Therefore, the data obtained, although they are determined with a certain error, can be used in the selection of effective techniques for separating curd dust from whey.

Further development of the research may be the establishment of factors under the influence of which the formation of curd dust occurs in the devices used for transportation of cheese grain and its cooling. In contrast to the process of formation of curd dust in the cheese-making vat, the corresponding processes in pumps and heat exchangers remain unstudied. This will make it possible to understand the reasons for the formation of dispersed protein in these devices and will create conditions for improving their designs, from the point of view of preventing the formation of curd dust.

7. Conclusions

1. The production of fermented milk cheese on modern mechanized lines is accompanied by the formation of a larger amount of curd dust compared to the production of this product in the traditional way using cheese vats. The content of curd dust in the total volume of whey removed during the production process of the product is from 4.26 to 5.3 kg/m^3, depending on the fat content of the main product. Raw material losses in the form of curd dust per 1000 kg of finished product average 27.3 kg.

The formation of a significant amount of curd dust and the fact that this process is not limited to the cheese-making vat is due to the more intense mechanical impact on the cheese grain in the devices of modern mechanized lines.

The formation of curd dust occurs during such processes as cutting and mixing cheese grain in the cheese-making vat, transporting the suspension using a cam pump, and cooling in a tubular heat exchanger. In the cheese-making vat, an average of 25% of curd dust is formed. The maximum amount of curd dust is not formed in the cheese-making vat, as was previously believed, but during the transportation of cheese grains from the cheese-making vat to the heat exchanger – 62% of the total amount. In the heat exchanger – 13%.

To reduce the level of curd dust formation, heat exchangers with minimal hydraulic resistance should be used to cool the cheese grains. This will make it possible to use softer pumps (compared to cam pumps) for transporting cheese grains from the cheese-making vat to the heat exchanger.

2. Curd dust formed during the production of the product on modern mechanized lines is characterized by smaller particle sizes compared to production in the traditional way. A significant part of the curd dust is concentrated in particles whose size does not exceed 0.5 mm. A significant proportion of curd dust, from 48% to 64% depending on the fat content of the product, is concentrated in particles smaller than 0.25 mm. The average size of curd dust depends on the fat content of the main product – when making a product with a higher mass fraction of fat, larger particles are formed than when producing a lower fat product.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

The data will be provided upon reasonable request.

Use of artificial intelligence

The authors declare the use of generative AI in the research and manuscript preparation process. According to the GAIDeT taxonomy (2025), the following tasks were delegated to generative AI tools under full human supervision:

– literature search and systematization;
– data collection.

Generative AI tool used: Chat-GPT-5.

Authors' contributions

Mariia Shynkaryk: Conceptualization, Project administration, Validation, Writing – review & editing, Investigation; **Oleh Kravets:** Methodology, Investigation, Data curation, Writing – original draft; **Roman Papernyak:** Formal analysis, Investigation, Visualization, Writing – original draft (translation); **Borys Lukiyanchuk:** Investigation, Resources.

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