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ASSESSMENT OF THE SAFETY OF DAIRY PRODUCTS BY NITRATE CONTENT DEPENDING ON THE SEASON OF PRODUCTION

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This study quantifies nitrate content in dairy products depending on heat treatment, technological features, and seasonal factors. The task addressed was to assess the nitrate content in dairy products in order to prevent the entry of high concentrations.

It was found that in the summer period, the nitrate content in drinking milk with different heat treatments did not exceed 5 mg/l. However, in the winter-spring period, an increase in the nitrate content in drinking milk was found, on average by 2.1 times, compared to milk in the summer period. This indicates that the nitrate content in drinking milk is mainly influenced by the seasonal factor.

It has been shown that the nitrate content in fermented milk products (yogurt, kefir) was practically similar to that in drinking milk. At the same time, in fermented milk cheese, an average of 2 times less than in yogurt and kefir was found. This indicates that nitrates pass into whey during the production technology of fermented milk cheese. However, the influence of starter cultures used in the production technologies of yogurt, kefir, and fermented milk cheese on the content of nitrates was not detected.

It was found that in soft cheeses in the winter-spring period, the amount of nitrates was on average 2 times higher, 16.5–21.3 mg/kg, than in the summer period, while the effect of the season on the content of nitrates in hard and processed cheeses was not detected. In powdered milk, the concentration of nitrates was the highest – 50–80 mg/kg, compared to other dairy products, which indicates the concentration of dry substances during production.

Thus, dairy products met the requirements of the EU regulation on the content of nitrates; the high concentrations detected in powdered milk indicate the need to control this product, especially when used for baby food

Keywords: nitrate content, drinking milk, fermented milk products, hard cheeses, powdered milk

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1. Introduction

Food safety is one of the principal factors for maintaining public health [1] as nutrition is the main route of entry of xenobiotics, including nitrates and nitrites, into the human body [2]. According to the World Health Organization (WHO), nitrates are one of the most common food contaminants that enter raw materials and processed products through feed, drinking water, and technological features of production [3]. Therefore, scientific research on the issues of ensuring the quality and safety of food products is important in the food industry.

In addition, high concentrations of nitrates in food products pose a danger to consumers as they increase the total amount of xenobiotics in the diet, which can cause intoxication and chronic pathologies. Nitrates in the human body do not exhibit acute toxic effects by themselves but they are capable of being reduced to nitrites, which, in turn, cause the oxidation of hemoglobin with the formation of methemoglobin, which reduces the transport function of the blood [4]. Secondary reactions of nitrites with amines and amides are especially dangerous, as a result of which nitroso compounds with pronounced carcinogenic potential are formed [5].

The results of monitoring studies on the content of xenobiotics in food products are extremely necessary for practice as they allow early detection of the problem of high concentrations and offer preventive measures, or devise technologies for their reduction. Therefore, research into the issue related to nitrates in dairy products is an important and urgent task of the modern food safety system.

2. Literature review and problem statement

Most studies in [6, 7] focused on vegetables and fruits as the main source of nitrates in human nutrition. It was shown that in leeks, carrots, arugula, bok choy, mizuna, and watermelon, the concentration of nitrates was higher than the maximum permissible concentration. Analysis of publications revealed increased humidity during the cultivation of these vegetables and fruits. Therefore, the issue of using a significant part of vegetables and fruits with high nitrate concentrations remains unresolved. An option for overcoming the relevant difficulties may be the use of various technological techniques (washing, mechanical cleaning, cooking) to reduce the nitrate content during use in food. This is the approach used in [8], which shows that during the process of salting and fermentation of plant raw materials, lactic acid species of autochthonous microorganisms-denitrifiers multiply and the amount of nitrates in the finished product decreases. However, almost all lactic acid bacteria used in dairy technology do not exhibit denitrifying ability.

At the same time, the issue of assessing dairy products in this aspect has remained less studied, although they constitute a significant share of children's and dietary nutrition where the permissible level of nitrates is especially important. Children are more sensitive to the toxic effects of nitrates [9] since they do not have fully formed enzyme systems that restore methemoglobin to hemoglobin. Therefore, the feasibility of conducting systematic studies on the nitrate content in dairy products is of particular relevance.

Literature data indicate that seasonality is one of the key factors in the variability of nitrate content in raw milk [10]. In particular, in the winter-spring period, when silage, haylage, and other feeds with a high nitrate content predominate in the diets of cows, there is an increase in nitric acid salts in raw milk. In contrast, in the summer period, under conditions of grazing and feeding animals with green fodder, the nitrate content in raw milk is usually lower [11]. At the same time, no data are provided on the preservation of such a trend in dairy products since different technologies and methods of product processing are used during the production of dairy products. The reason for this may be objective difficulties associated with the fact that the assessment of nitrate content in milk and dairy products is not carried out sufficiently since the standard method using a cadmium column is laborious. Therefore, real data showing the nitrate content in dairy products of different groups are insufficient to draw a conclusion about the safety of this category of products in terms of xenobiotics. An option to overcome the relevant difficulties may be the introduction of a system for monitoring the nitrate content in dairy products that are produced.

It has been found that the nitrate content in milk can be different, in particular, extremely high concentrations of up to 146 mg/l are reported [12]. At the same time, the authors note that there is no significant difference in the nitrate content between samples of sheep, goat and cow milk. That is, as follows from the studies, dairy products made from milk from different animal species can serve as a significant source of nitrates. Work [13] indicates that cow's milk is one of the most important food products for children, therefore the detection of nitrates and nitrites in it is of great importance for ensuring health. It was found that the average nitrate concentration in colostrum-enriched milk ranged from 14.1 to 136 mg/l, in whey-enriched milk 42.6–242.8 mg/l, and in regular milk 57.9–157.6 mg/l. At the same time, it is not reported whether the nitrate concentration data in milk meet the standards, which significantly reduces the value of these studies in terms of safety interpretation.

Other researchers [14] found a significantly lower nitrate content in milk, with a mean value of 34 ± 11 mg/l. Although the average nitrate intake in all age groups was lower than the recommendations by the World Health Organization, the assessment of this xenobiotic requires constant monitoring in dairy products due to its significant fluctuations. The authors do not report on the reasons that affect the nitrate concentration in dairy raw materials. In addition, in work [15], during the study of powdered milk, a nitrate concentration of an average of 35 mg/l was found. All this allows us to state that it is advisable to conduct a study aimed at clarifying the influence of modern methods for heat treatment (pasteurization, sterilization, ultra-high temperature treatment) on the nitrate content in finished products.

Study [16] indicated the possibility of using special denitrifying microorganisms in the production technologies of fermented milk products, since raw materials with an excessive content of nitric acid salts may be processed. This confirms the need and prospects for conducting research on controlling the content of nitrates in dairy products as it would prevent the intake of dangerous concentrations of nitric acid salts into the diet of consumers. An equally important aspect is the analysis of the impact of technological production processes (heat treatment, fermentation) on changes in nitrate concentrations in finished products.

Therefore, it is advisable to study nitrate concentrations in drinking milk and various dairy products in a seasonal aspect, which could make it possible to improve the system for controlling the safety of food production and reducing potential risks to consumer health.

3. The aim and objectives of the study

The aim of our study was to quantify the nitrate content in dairy products depending on the season, type of product, and processing technology, which would provide an opportunity to justify the introduction of technologies that could prevent the ingress of high concentrations.

To achieve this goal, the following tasks were set:

– to determine the actual concentration of nitrates in drinking milk under different heat treatment;

– to determine the actual concentration of nitrates in fermented milk products using different starter cultures;

– to quantify the nitrate content in hard, soft, processed cheeses, and powdered milk.

4. The study materials and methods

The object of our study is the regularity of nitrate content in dairy products depending on heat treatment, technological features, and seasonal factors.

The principal hypothesis assumes the possibility of the influence of the seasonal factor, heat treatment of milk, and the technology of production of various dairy products on the concentration of nitrates in them. It was assumed that the production technology of certain groups of dairy products is different, and accordingly the distribution of nitrates and the final concentration in finished products would be different. In addition, it was believed that the seasonal factor may have an impact on the concentration of nitrates in dairy products.

For the study, samples of drinking milk of various heat treatment (pasteurized, sterilized, ultra-high temperature – UHT), fermented milk products (kefir, yogurt, fermented milk cheese), and cheeses (hard, processed, soft), as well as powdered milk, were selected. Samples of dairy products were taken in the summer (June-August) and winter-spring (January-March) periods. In total, more than 180 samples of dairy products from the retail trade network were analyzed, which met the current requirements of DSTU for labeling and shelf life.

Sampling was carried out in accordance with the requirements of DSTU ISO 707:2002 "Milk and dairy products. Guidelines for sampling". Samples were delivered to the laboratory in a cooled state (+4°C) and were subject to analysis no later than 24 hours after purchase. At least three parallel determinations were carried out for each group of products.

For this purpose, the standard reference method of cadmium column or cadmium reduction research with subsequent spectrophotometric analysis according to DSTU ISO 14673-3:2004 IDF 189-3:2004 was used. The essence of the method is the reduction of nitrates to nitrites using metallic cadmium in a special column. The formed nitrites react with the reagents sulfonamide and N-naphthylamine, forming a bright pink azo compound. The intensity of this color was measured on a spectrophotometer at 540 nm [17].

To ensure the reliability of results, a quality control system was used, which included the following elements. Standard solutions (references) were prepared at precisely known nitrate concentrations to construct a calibration curve. Reduction control involved checking the efficiency of the cadmium column by analyzing samples with a known nitrate content. Spike samples were prepared by artificially adding known nitrate concentrations to assess the accuracy of the method under real matrix conditions [17].

The obtained experimental data were processed using variational statistics methods. The results were represented as the mean value (M) and the standard error of the mean ($\pm m$). The statistical significance of the differences between the means was determined by the Student test at a confidence level of $p \leq 0.05$. The results were processed using the Statistica 12.0 software (StatSoft, USA) and MS Excel 2019 (USA).

5. Results of studies on the assessment of nitrate concentrations in dairy products depending on the seasonal factor

5. 1. Determining the actual concentration of nitrates in drinking milk with different heat treatment

The results from determining nitrates in milk in the summer months are shown in Fig. 1.

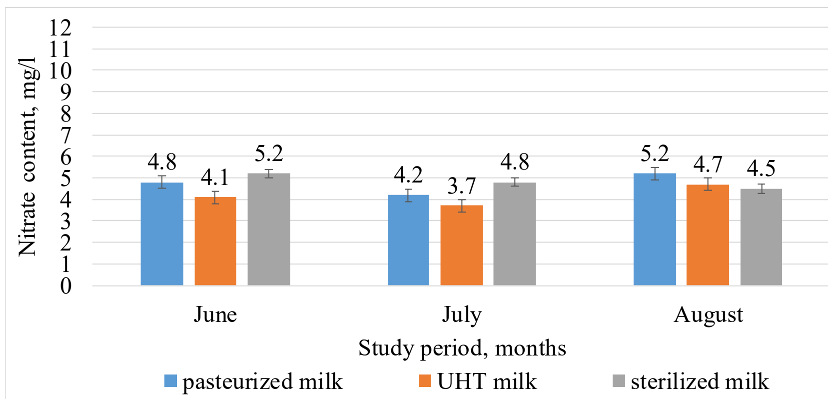

Fig. 1. Nitrate content in drinking milk at different heat treatment in the summer period, $n = 27$, $M \pm$ m

Fig. 1 shows that the concentration of nitrates in drinking milk did not change significantly during summer months, depending on the heat treatment technique. In June, the lowest nitrate content was found in UHT milk – 4.1 ± 0.3 mg/l, and the highest content was observed in sterilized milk – 5.2 ± 0.4 mg/l, that is, the difference was not statistically significant. In July, a decrease in the indicator was observed in all samples, especially in UHT milk to 3.7 ± 0.3 mg/l; in August, the amount of nitrates increased again, reaching a maximum in pasteurized milk of 5.2 ± 0.4 mg/l. However, these data also did not differ significantly from each other.

Thus, the study shows that in drinking milk at different heat treatment in the summer months the concentrations of nitrates fluctuated within 3.7–5.2 mg/l. This indicates that heat treatment does not affect the total nitrate content in drinking milk and this type of product is not considered a significant source of nitrates in the overall diet of consumers.

The results of the study of nitrate concentrations in drinking milk during heat treatment in the winter-spring period are shown in Fig. 2.

Fig. 2 shows that in January the highest values of nitrate concentration in drinking milk samples were recorded in UHT and sterilized milk – 10.5 ± 0.6 mg/l, and the lowest in pasteurized milk – 8.9 ± 0.5 mg/l, i.e., the difference was not significant.

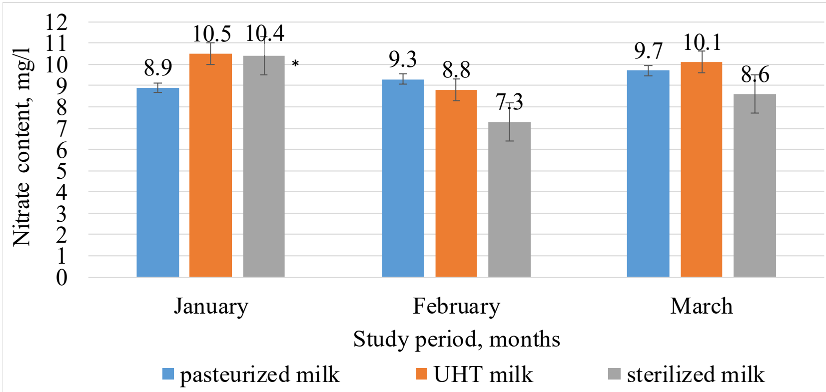

Fig. 2. Nitrate content in drinking milk at different heat treatment in the winter-spring period, $n = 27$, $M \pm$ m

In February, the nitrate concentration in sterilized milk was 1.4 times lower ($p \leq 0.5$) (7.3 ± 0.4 mg/l), compared with such milk in January. At the same time, no statistical difference was found between drinking milk and UHT milk in that month. In March, no significant difference in nitrate concentration in milk of different treatments was found, the content fluctuated within 8.6–10.1 mg/l.

Comparison of the dynamics of nitrate content in drinking milk of different heat treatment in the winter-spring and summer periods revealed clear seasonal differences. In the winter-spring period, the nitrate concentration was significantly higher, mainly 8.6–10.5 mg/l. In the summer period, a decrease in the level of nitrates in drinking milk to 3.7–5.2 mg/l was observed, i.e., drinking milk is sold in this period, which had a 2.2–2.0 times ($p \leq 0.5$) lower nitrate concentration than in the winter-spring period.

In general, our data indicate that the concentration of nitrates in drinking milk depends on the season, while the heat treatment technique does not significantly affect their content. In all studied samples, the concentration of nitrates remained within 5–10 mg/kg.

5. 2. Determining the actual concentration of nitrates in fermented milk products using various starter cultures

In the production technology of fermented milk products, starter cultures are used to ferment raw materials; therefore, from a scientific point of view, studies on determining the concentration of nitrates in these types of products were of interest. The results of studies on the assessment of fermented milk products by nitrate concentration in the summer period are shown in Fig. 3.

From Fig. 3, one can see that in the summer period the nitrate content in fermented milk products was characterized by variable values of indicators. In particular, in June, the nitrate concentration was the highest in kefir 4.7 ± 0.2 mg/l, and the lowest in fermented milk cheese – 2.1 mg/l, i.e., 2.2 times ($p \leq 0.5$) lower content. In July, an increase in the nitrate concentration was noted in all samples of fermented milk products with a maximum value in kefir 5.9 ± 0.3 mg/l. At the same time, no significant difference between them in terms of nitrate values in these products in the studied month was recorded.

In August, a decrease in the nitrate concentration in the studied fermented milk products to the level that was inherent in June was noted – 2.8–3.4 mg/l. If we compare the nitrate content in fermented milk products in the summer months with each other, we observe, on average, a 1.5–1.7 times higher concentration in July, compared to June and August.

The results of our study on the assessment of fermented milk products by the nitrate content in fermented milk products in the winter-spring period are shown in Fig. 4.

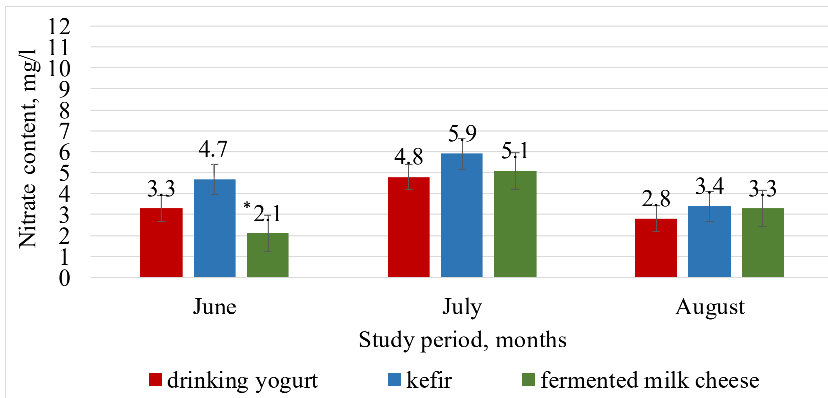

Fig. 3. Nitrate content in fermented milk products in the summer, $n = 27$, $M \pm m$

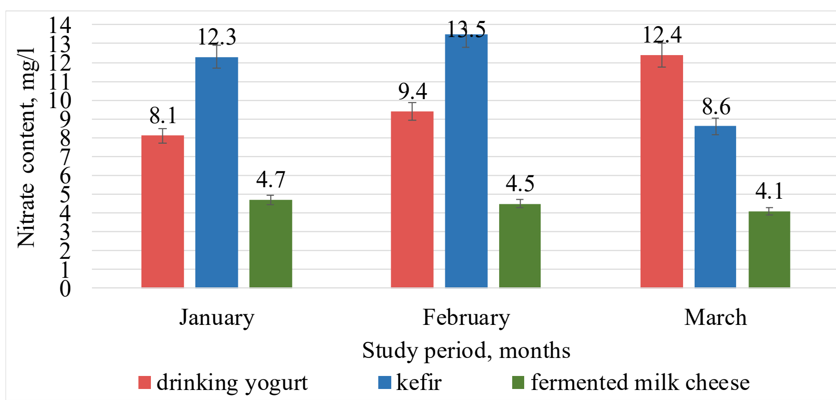

Fig. 4. Nitrate content in fermented milk products in the winter-spring period, $n = 27$, $M \pm m$

From the analysis of the data in Fig. 4 it is clear that in the winter period the nitrate content in different types of fermented milk products differs significantly from each other. In January, the lowest nitrate concentrations were recorded in yogurt samples – 8.1 ± 0.4 mg/l; 1.5 times ($p \leq 0.5$) higher amount is recorded in kefir – 12.3 ± 0.5 mg/l, and the lowest in fermented milk cheese 4.7 ± 0.2 mg/l. That is, in fermented milk cheese during this period the nitrate content was 1.7 times ($p \leq 0.5$) lower than in yogurt and 2.6 times ($p \leq 0.5$), compared with the content in kefir.

If we characterize the nitrate content in fermented milk products studied in February–March, we can note similar results that were observed in January. In particular, the highest levels of these salts were recorded in yogurt and kefir – 12.4 ± 0.5 mg/l and 8.6 ± 0.3 mg/l, respectively; and 3.0–2.1 times ($p \leq 0.5$) lower in fermented milk cheese.

In general, when comparing the nitrate content in fermented milk products studied in the summer and winter-spring periods, we note a trend that was inherent in drinking milk. That is, products such as kefir and yogurt were characterized by an average of 2.5 times ($p \leq 0.5$) higher content of nitrate salts in the winter-spring period than in the summer. In contrast, in fermented milk cheese, the nitrate content did not differ significantly in the samples studied in summer and winter, and did not exceed a concentration of 5 mg/l.

Therefore, our results indicate that in the winter period there is a higher probability of nitrate accumulation in fermented milk products than in the summer. In addition, traditional starter cultures used in the production technologies of yogurt, kefir, and fermented milk cheese did not affect the nitrate content when compared to the content in drinking milk. This necessitates the need for enhanced control over raw materials and technological processes.

5. 3. Assessment of nitrate content in hard, soft, processed cheeses, and powdered milk

In addition to the study of fermented milk products, an assessment of hard cheeses and powdered milk was carried out for nitrate content in different periods of the year. The results of studies of these products in the summer period are shown in Fig. 5.

The data in Fig. 5 indicate significant fluctuations in nitrate concentration, depending on the type of product and the month of the study. In particular, in the studied hard cheeses, a sharp increase of 2.0 times ($p \leq 0.5$) in nitrate content in July to 44.1 ± 1.7 mg/kg, compared to June, and a further decrease in August to a concentration of 12.3 ± 0.6 mg/kg is observed. Such fluctuations in nitrate content in cheeses are probably associated with different production technologies and different contents of these salts in milk. In processed cheeses purchased in the summer months, nitrate content indicators remained relatively stable, since quantitative values fluctuated within a fairly narrow range of 36.3–51.6 mg/kg, which indicates the preservation of high nitrate levels throughout the summer.

Soft cheeses were characterized by the lowest nitrate content among the studied products from 7.3 ± 0.3 mg/kg in July to 12.1 ± 0.5 mg/kg in June, without sharp changes in dynamics. In contrast, the highest nitrate concentrations were recorded in powdered milk, which during the summer months increased from 55.8 ± 2.7 mg/kg in June to 78.3 ± 3.8 mg/kg in July, maintaining a consistently high concentration in August – 74.5 ± 3.6 mg/kg. That is, in powdered milk the nitrate concentration was several times higher than in hard cheeses, approximately 1.5–2 times higher than in processed cheeses and 5–10 times higher than in soft cheeses.

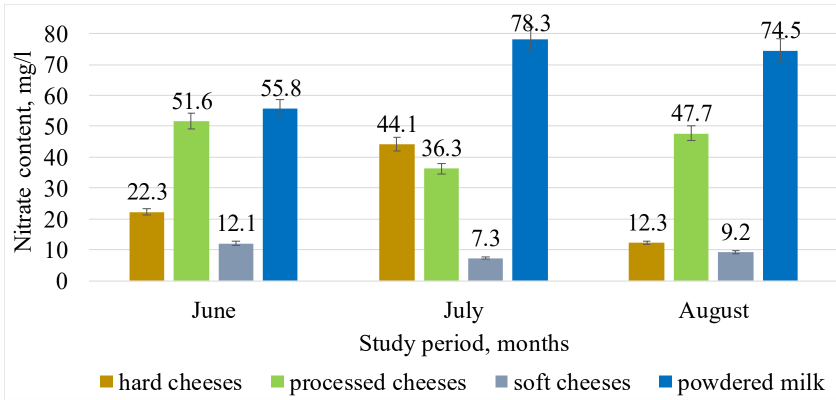

Fig. 5. Nitrate content in cheeses and powdered milk in the summer, $n = 36$, $M \pm m$

Thus, our results indicate that the nitrate content in dairy products (hard, soft cheeses) significantly depends on their type and season. At the same time, the concentration of nitrates in powdered milk in the summer period significantly exceeded the indicators, compared with other types of dairy products.

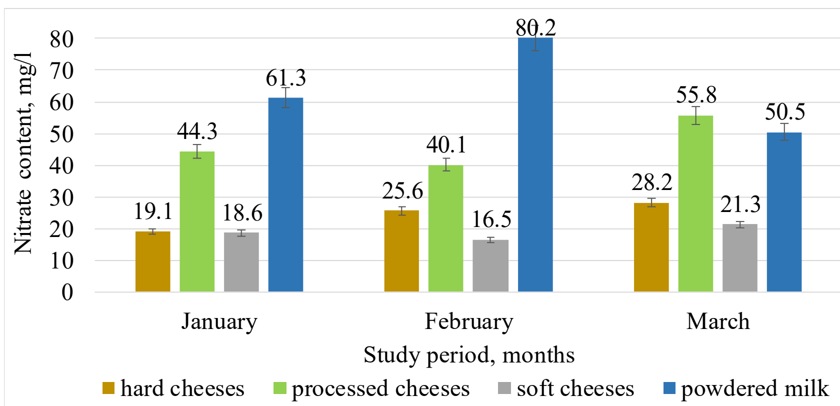

Fig. 6. Nitrate content in cheeses and powdered milk in the winter-spring period, $n = 36$, $M \pm m$

The results of studies on assessing nitrate levels in cheeses and powdered milk are shown in Fig. 6.

Fig. 6 shows that in cheeses and powdered milk purchased in the winter-spring period, the nitrate content had similar values as in these products sampled in the summer. That is, powdered milk also contained the largest amount of nitrates in the winter-spring period, while the lowest values were characteristic of soft cheeses. At the same time, when comparing the two seasons, the difference in soft cheeses was particularly significant, which showed that in the summer period they contained the lowest nitrate concentrations of 7.3–12.1 mg/kg. In the winter-spring period, these values almost doubled to 16.5 and 21.3 mg/kg, respectively. Powdered milk during both periods retained the highest level of nitrates among the studied products. In summer, the maximum nitrate concentrations were 78.3 ± 3.8 mg/kg, while in the winter-spring period – 80.2 ± 4.1 mg/kg, i.e., no significant difference was observed between these indicators.

Thus, among cheeses, hard cheeses are the most unstable to nitrate accumulation, while soft cheeses had the lowest concentration. At the same time, regardless of the season of the year, powdered milk remains the product with the highest nitrate content.

6. Research on nitrate content in dairy products and compliance with regulatory requirements: results and summary

Dairy products are an important source of nutrients [18], but they can contain chemicals, in particular nitrates, which, if consumed in excess, pose a health risk to consumers [2]. Studies have shown that the concentration of nitrates in drinking milk did not depend on the heat treatment technique (pasteurization, sterilization, UHT) in both the summer and winter-spring periods. In the summer months, nitrate levels were 3.7–5.2 mg/l (Fig. 1), while in the winter-spring period the concentration increased to 8.6–10.5 mg/l (Fig. 2). This is consistent with data [10] that link the increase in nitrate content in milk in winter with feeding characteristics and weaker nitrate-reducing activity of the rumen microbiota of cows. As a result, in the summer cows consume more nitrates with green fodder, while the nitrate content in milk is lower, in winter less nitrates come with feed, but the concentration in milk is higher. During monitoring studies of the nitrate content in raw cow's milk throughout the year, the authors of [11] also found a seasonal effect on their concentration. At the same time, in the winter period, the number of samples with a nitrate content of more than 10 mg/l was approximately 20%, and in the summer – about 2%. At the same time, results are also given about significantly higher nitrate concentrations in cow's milk. Thus, in studies [12, 13], when assessing drinking cow's milk, nitrate concentrations of up to 160 mg/l were found; the authors do not indicate the factors that could have influenced such content of this xenobiotic. According to EU Regulation No. 1258/2011, the permissible level of nitrates in food (infant formula) is 50 to 100 mg/kg, depending on the vegetable filler [19]. Researchers [11] indicate that the permissible nitrate content in raw milk for processing is considered to be a concentration of 10 mg/l, as was the case in the previous standard. In addition, the Chinese national standards GB 2761-2017 and GB 2762-2017 regulate the content of nitrites in raw milk, and they should not exceed 0.4 mg/kg and 4 mg/kg in powdered milk [20].

The results showed that even during the period of the highest nitrate content in dairy products (January–March), the concentration remained within the permissible limits, but in some samples it approached the limit of the norm of 50 mg/kg. This indicates a possible risk if such products are consumed systematically by people with impaired intestinal microflora [2, 8]. We also believe that the quantitative values of nitrate content in milk and dairy products may differ from each other when using different methods of determination. Since there are currently several methods for determining nitrates (colorimetric, ion chromatography, cadmium or reduction, using portable nitratometers, rapid tests), it is necessary to use a standard detection method.

Our study of fermented milk products (kefir, yogurt, fermented milk cheese) showed that in the winter-spring period, the nitrate concentration in kefir and yogurt was 2.0–2.5 times higher (8.6–12.4 mg/l) (Fig. 3) than in the summer (2.8–5.9 mg/l) (Fig. 4). The lowest nitrate content values were recorded in fermented milk cheese regardless of the study period (2.1–4.7 mg/l) (Fig. 3, 4), which is probably explained by the technology of its production, since part of the nitrates is excreted together with the whey. In addition, researchers note that additional starter cultures that exhibit denitrifying properties can be used to reduce the nitrate content in the technology of fermented milk products production [16]. Classical lactic acid bacteria used for fermentation of dairy raw materials do not exhibit denitrifying ability. This indicates that yogurts and kefir may contain elevated concentrations of nitrates, which is dangerous for consumers with increased sensitivity to these salts (children, pregnant women).

Among cheeses, the highest nitrate concentrations were recorded in hard cheeses – up to 44.1 ± 1.7 mg/kg, and processed cheeses – 36.3–51.6 mg/kg (Fig. 5). The lowest nitrate content values were observed in soft cheeses, which were 7.3–21.3 mg/kg (Fig. 5, 6), which depended on the period of the study. These nitrate content indicators do not exceed the standards of European regulations and the International Dairy Federation for hard cheeses, up to 150 mg/kg [21]. At the same time, in work [22] it was found that 50% of cheese samples in Turkey had nitrate content exceeding the permissible level specified in EU Regulation No. 1881/2006.

Special attention is paid to powdered milk, in which the nitrate content was the highest among all the products studied, in particular 55.8–78.3 mg/kg in the summer period (Fig. 5) and 80.2 ± 4.1 mg/kg in the winter-spring period (Fig. 6). This is several times higher than the nitrate content in hard cheeses and dozens of times higher than in soft cheeses. The high values are probably explained by the concentration of dry matter in the production process, which leads to the accumulation of nitrates. These results are consistent with the data from [21], which show that the nitrate content in cheeses can vary significantly depending on the production technology, type of cheese and raw materials used. The authors emphasize that although nitrates can be a natural component of food products, their excess is associated with the danger of forming nitroso compounds [22]. As noted in [23], in people with chronic diseases of the stomach and intestines, the utilization of nitrates by the colonic microbiome slows down. Therefore, the amount of nitrates required for the occurrence of chronic nitrate poisoning will be lower [24]. Therefore, we support the opinion of researchers [3, 11, 25] regarding the need to reduce the maximum permissible amount of nitrates in dairy products, especially for baby food.

According to the hygiene requirements of EU Regulation No. 1258/2011, the maximum permissible nitrate content in dairy baby products is 50–100 mg/kg [19], while there are no maximum permissible standards for fermented milk products. Although the European Regulation allows nitrate content up to 150 mg/kg in the technology of hard cheeses, it should be noted that according to US regulations, the addition of nitrates to the technology of cheese production is prohibited [21]. The results indicate that in the studied samples the nitrate content indicators were within the regulatory values. However, in powdered milk, the nitrate concentration in some cases reached significant indicators of up to 100 mg/kg, which may create additional danger in the event of its mass use in the food industry (in particular, in infant formulas).

In general, our results indicate that the nitrate content in dairy products significantly depends on the period of the year in which these products were manufactured, apparently due to the influence of the quality of rations for cows. In contrast, heat treatment of milk has no effect on the nitrate content. The revealed patterns from a practical point of view make it possible to propose increased control over the safety of dairy products in the winter-spring period for this xenobiotic. In addition, it was found that the greatest risk is posed by powdered milk, hard and processed cheeses, in which the nitrate content can reach the maximum regulatory values. Therefore, an applied aspect of using the obtained scientific data is the possibility of proposing the use of milk with a significant nitrate content for the production of products, in particular fermented milk cheese, during the technology of which they are removed with secondary raw materials.

Taking into account our results and data from the literature [2, 25], which indicate that prolonged consumption of products with a high nitrate content leads to the formation of nitroso compounds and the development of chronic pathologies, special attention is required to introduce systematic monitoring of raw materials for nitrate content, improve technological processes for the production of hard and processed cheeses, and control of powdered milk, particularly when used for baby food.

Thus, our results revealed that dairy products, in general, do not exceed the standards for nitrate content. At the same time, individual groups (powdered milk) may pose a potential risk to consumers, which makes further research and the development of preventive measures at all stages of production relevant. At the same time, limitations on the application of the findings may consist in the need for larger-scale scientific research covering raw materials and dairy products manufactured in different regions. In addition, there are shortcomings in the implementation of a system for monitoring dairy products for nitrate content, as it requires the allocation of additional funds for laboratory research. It is the lack of funding for the state program for monitoring nitrates in dairy products that may become a problem for the implementation of research.

However, this study could be further advanced, both from a practical and theoretical perspective. The results may contribute to the development of new, rapid technical methods for assessing the content of nitrates in food products and the improvement and implementation of biological techniques for their denitrification.

7. Conclusions

1. We have established that the nitrate content in drinking milk throughout the year did not depend on the heat treatment technique (sterilization, pasteurization, UHT), while the seasonal factor had an influence. In particular, in the summer period, the amount of nitrates in milk ranged from 3.7 ± 0.3 mg/l to 5.2 ± 0.4 mg/l and was on average 2.1 times lower than milk sold in the winter-spring period. In all the studied milk samples, the nitrate content practically did not exceed the standard of 10 mg/l.

2. It was found that the starter lactic acid microorganisms used in the technology of yogurt and kefir production do not affect the nitrate content in the finished product, since the indicators were practically similar to those in drinking milk. In contrast, in fermented milk cheese, a lower nitrate content was noted, in particular, in the winter-spring period, the amount of nitric acid salts was 1.7 times lower than in yogurt and 2.6 times lower than in kefir. This indicates the influence of the production technology of fermented milk cheese on the nitrate content in the finished product.

3. We have found that the nitrate content in hard and processed cheeses did not change significantly during the year and was 12.3–44.1 mg/g and 36.3–55.8 mg/kg, respectively. In soft cheeses, an average of 2 times higher content (16.5–21.3 mg/kg) was noted in the winter-spring period, compared to the summer. Among all the dairy products studied, the highest nitrate content was in powdered milk – 50.5–80.2 mg/kg. That is, the amount of nitrates in this product was several times higher than in hard cheeses, 1.5–2.0 times higher than in processed cheeses, and 5–10 times higher than in soft cheeses. This indicates that powdered milk and products based on it could be an additional source of nitrates.

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

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

The paper uses Ukrainian Voice 5.1 artificial intelligence for spelling editing of the text.

Authors' contributions

Mykola Kukhtyn: Conceptualization, Writing – Drafting, **Vyacheslav Laiter:** Investigation; **Svitlana Laiter-Moskaliuk:** Investigation, Validation; **Yuliia Horiuk:** Writing – Reviewing and editing. Formal analysis; **Anatolii Dymchuk:** Methodology; **Volodymyr Salata**: Writing – Reviewing and editing; **Mariia Khimych:** Investigation; **Larysa Kladnytska:** Resources.

References

1. Yukalo, V., Datsyshyn, K., Storozh, L. (2019). Electrophoretic system for express analysis of whey protein fractions. Eastern-European Journal of Enterprise Technologies, 2 (11 (98)), 37–44. https://doi.org/10.15587/1729-4061.2019.160186

2. Karwowska, M., Kononiuk, A. (2020). Nitrates/Nitrites in Food – Risk for Nitrosative Stress and Benefits. Antioxidants, 9 (3), 241. https://doi.org/10.3390/antiox9030241
3. Flores, M., Toldrá, F. (2021). Chemistry, safety, and regulatory considerations in the use of nitrite and nitrate from natural origin in meat products - Invited review. Meat Science, 171, 108272. https://doi.org/10.1016/j.meatsci.2020.108272
4. Patel, N., Srivastav, A. L., Patel, A., Singh, A., Singh, S. K., Chaudhary, V. K. et al. (2022). Nitrate contamination in water resources, human health risks and its remediation through adsorption: a focused review. Environmental Science and Pollution Research, 29 (46), 69137–69152. https://doi.org/10.1007/s11356-022-22377-2
5. Ward, M., Jones, R., Brender, J., De Kok, T., Weyer, P., Nolan, B. et al. (2018). Drinking Water Nitrate and Human Health: An Updated Review. International Journal of Environmental Research and Public Health, 15 (7), 1557. https://doi.org/10.3390/ijerph15071557
6. Mehri, F., Heshmati, A., Moradi, M., Khaneghah, A. M. (2019). The concentration and health risk assessment of nitrate in vegetables and fruits samples of Iran. Toxin Reviews, 40 (4), 1215–1222. https://doi.org/10.1080/15569543.2019.1673424
7. Hosseini, M.-J., Dezhangah, S., Esmi, F., S. Gharavi-nakhjavani, M., Hashempour-baltork, F., Mirza Alizadeh, A. (2023). A worldwide systematic review, meta-analysis and meta-regression of nitrate and nitrite in vegetables and fruits. Ecotoxicology and Environmental Safety, 257, 114934. https://doi.org/10.1016/j.ecoenv.2023.114934
8. Kukhtyn, M., Horiuk, Y., Yaroshenko, T., Laiter-Moskaliuk, S., Levytska, V., Reshetnyk, A. (2018). Effect of lactic acid microorganisms on the content of nitrates in tomato in the process of pickling. Eastern-European Journal of Enterprise Technologies, 1 (11 (91)), 69–75. https://doi.org/10.15587/1729-4061.2018.120548
9. Pinaffi-Langley, A. C. da C., Nguyen, H. V. M., Whitehead, D., Roseland, J. M., Heydorn, K. C., Wu, X. et al. (2025). Nitrate and nitrite quantification in U.S. vegetable-based baby foods and infant formula via ozone chemiluminescence. Journal of Food Composition and Analysis, 137, 106902. https://doi.org/10.1016/j.jfca.2024.106902
10. Laiter, V. V., Kukhtyn, M. D., Dymchuk, A. V., Laiter-Moskaliuk, C. V. (2025). Estimation of nitrate content in raw cow's milk during the year. Podilian Bulletin: agriculture, engineering, economics, 48, 43–51. https://doi.org/10.37406/2706-9052-2025-3.5
11. Pyskiv, S., Kuhtyn, M. (2018). Monitoring the content of nitrates in milk. Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Food Technologies, 20 (85), 41–45. https://doi.org/10.15421/nvlvet8508
12. Licata, P., Naccari, F., Di Bella, G., Lo Turco, V., Martorana, V., mo Dugo, G. (2013). Inorganic anions in goat and ovine milk from Calabria (Italy) by suppressed ion chromatography. Food Additives & Contaminants: Part A, 30 (3), 458–465. https://doi.org/10.1080/19440049.2012.747222
13. Yeh, T. S., Liao, S. F., Kuo, C. Y., Hwang, W. I. (2013). Investigation of the Nitrate and Nitrite Contents in Milk and Milk Powder in Taiwan. Journal of Food and Drug Analysis, 21 (1), 73–79. https://doi.org/10.6227/jfda.2013210109
14. Chamandust, S., Mehrasebi, M. R., Kamali, K., Solgi, R., Taran, J., Nazari, F., Hosseini, M.-J. (2016). Simultaneous Determination of Nitrite and Nitrate in Milk Samples by Ion Chromatography Method and Estimation of Dietary Intake. International Journal of Food Properties, 19 (9), 1983–1993. https://doi.org/10.1080/10942912.2015.1091007
15. Mohammadpour, A., Samaei, M. R., Baghapour, M. A., Alipour, H., Isazadeh, S., Azhdarpoor, A., Mousavi Khaneghah, A. (2024). Nitrate concentrations and health risks in cow milk from Iran: Insights from deterministic, probabilistic, and AI modeling. Environmental Pollution, 341, 122901. https://doi.org/10.1016/j.envpol.2023.122901
16. Kukhtyn, M., Salata, V., Horiuk, Y., Kovalenko, V., Ulko, L., Prosyanyi, S. et al. (2021). The influence of the denitrifying strain of Staphylococcus carnosus No. 5304 on the content of nitrates in the technology of yogurt production. Potravinarstvo Slovak Journal of Food Sciences, 15, 66–73. https://doi.org/10.5219/1492
17. Chetty, A. A., Prasad, S. (2016). Flow injection analysis of nitrate and nitrite in commercial baby foods. Food Chemistry, 197, 503–508. https://doi.org/10.1016/j.foodchem.2015.10.079
18. Yukalo, V. G., Storozh, L. A. (2018). Isolation of ϰ-CN-1P and Β-CN-5P fractions from native casein micelles. The Ukrainian Biochemical Journal, 90 (4), 74–79. https://doi.org/10.15407/ubj90.04.074
19. Kmecl, V., Žnidarčič, D., Franić, M., Ban, S. G. (2019). Nitrate and nitrite contamination of vegetables in the Slovenian market. Food Additives & Contaminants: Part B, 12 (3), 216–223. https://doi.org/10.1080/19393210.2019.1600589
20. Liu, C., Wang, N., Liu, L., Zhang, Y., Liu, Y. (2024). An analytical overview of the composition and characteristics of China's food safety standards. Journal of the Science of Food and Agriculture, 104 (6), 3197–3205. https://doi.org/10.1002/jsfa.13262
21. Naturally occurring nitrates in cheese (2020). Available at: https://www.ukidf.org/documents/Factsheet_15Naturallyoccuringnitratesincheese.pdf?utm_source=chatgpt.com
22. Sungur, Ş., Atan, M. M. (2013). Determination of nitrate, nitrite and perchlorate anions in meat, milk and their products consumed in Hatay region in Turkey. Food Additives and Contaminants: Part B, 6 (1), 6–10. https://doi.org/10.1080/19393210.2012.717108
23. Deveci, G., Tek, N. A. (2023). N-Nitrosamines: a potential hazard in processed meat products. Journal of the Science of Food and Agriculture, 104 (5), 2551–2560. https://doi.org/10.1002/jsfa.13102
24. Kalaycıoğlu, Z., Erim, F. B. (2019). Nitrate and Nitrites in Foods: Worldwide Regional Distribution in View of Their Risks and Benefits. Journal of Agricultural and Food Chemistry, 67 (26), 7205–7222. https://doi.org/10.1021/acs.jafc.9b01194
25. Jiang, H., Tang, Y., Garg, H. K., Parthasarathy, D. K., Torregrossa, A. C., Hord, N. G., Bryan, N. S. (2012). Concentration- and stage-specific effects of nitrite on colon cancer cell lines. Nitric Oxide, 26 (4), 267–273. https://doi.org/10.1016/j.niox.2012.03.010