Comparison of natural curd whey and its nanoconcentrate in regard to the nutritional and biological value

V B Shevchuk¹, R V Shutro¹,², A I Gnezdilova¹, E A Fialkova¹, Yu V Vinogradova¹

¹ Federal State Budgetary Educational Institution of Higher Education ‘The Vereshchagin Vologda State Dairy Farming Academy’, 2, Shmidt St., Molochnoye, Vologda, 160555, Russia Federal
² E-mail: roma-shutro@mail.ru

Abstract. The article is devoted to studying the effect of membrane filtration on the change in the biological value of natural curd whey and its nanoconcentrate. As the statistics shows, no more than 20% of natural curd whey is subjected to deep processing. Some techniques for increasing the dry matter concentration have been considered, and their disadvantages have been identified. The most up-to-date technique – nanofiltration – has been chosen, the main advantages of which are high efficiency of concentration and partial demineralization effect during whey processing. The purpose of the work is to study the effect of nanofiltration treatment on the change in the amino acid composition of natural curd whey and nanoconcentrate. The work studies the natural curd whey received in the process of low-fat. Experimental data showing the essential amino acids content have been obtained. The amino acids content was determined by gas chromatography. The calculation of the amino acid score in natural curd whey and its nanoconcentrate has been done. Limiting amino acids have been found both in natural curd whey and nanoconcentrate. The values of comparable redundancy index, the essential amino acids index, and the utility coefficient were calculated and compared. Using the obtained calculations, it is possible to conclude that the nanoconcentrate in comparison with natural curd whey has a higher balance of essential amino acids, their number increases, and it is necessary to take these data into account when developing new types of products having increased biological value.

1. Introduction
At present, curd whey production in the country is not less than 2.5 million tons [1]. At the same time, not more than 20% of curd whey undergoes deep processing, and most part of it is simply disposed of, which is negative from the environmental and economic point of view.

Meeting the challenges facing dairy product manufacturers to increase production volumes and reduce production costs, one of the directions is saving resources, since raw material costs average 60-70% of dairy products net cost, depending on the region of Russia [2]. One of the directions of resource saving is complex processing of dairy raw materials, including whey.

Low rates of curd whey processing are connected with its high relative mineral content with its almost twice as low dry matter content compared to whole milk. However, whey is the most valuable dairy raw material, and the products of its deep processing have a high level of added value. There are various techniques for increasing the dry matter concentration in food raw materials: concentration by freezing [3], evaporation, and drying. These techniques have a number of disadvantages: high energy costs, efficient and expensive production equipment that is difficult to maintain. The most promising
techniques are based on membrane separation methods. Microfiltration, ultrafiltration, reverse osmosis, and electrodialysis technologies proved to be productive in this field. At the same time, it is worth mentioning nanofiltration technology, the main advantages of which are high efficiency of concentration and the effect of partial demineralization while whey is processed. Nanofiltration of natural curd whey allows one to obtain whey concentrates with dry matter content from 6 to 22% [4]. Due to partial removal together with the filtrate of some minerals and lactic acid from the whey, these concentrates have good organoleptic indices. This allows one to use nanoconcentrates in most traditional dairy products as a basis for developing a range of new food products, including in related food industries: confectionery, bakery and others [5,6,7].

For instance, the authors [8] emphasize that it is necessary, while preparing diets, especially for athletes, to enrich them with products containing a selected set of proteins, carbohydrates and minerals. This concept is met by using curd whey concentrates rich in carbohydrates, minerals and complete protein. The aim of this work is studying the effect of nanofiltration treatment on the change of amino acid composition in natural curd whey concentrate.

2. Research objects and materials
This paper studies the natural curd whey obtained in the process of manufacturing low-fat curd on the production line (Russian brand ‘Я9-ОПТ’) at the JSC ‘Experimental-training dairy plant’ of Vereshchagin Vologda State Dairy Farming Academy, for the content of essential amino acids and their change after the nanofiltration process. The average values of the main process parameters of curd whey are presented in table 1.

| Parameter             | Literature data [7] | Average values of the investigated natural curd whey |
|-----------------------|---------------------|------------------------------------------------------|
| Dry matter content, % | 4,2-7,4             | 6,3                                                  |
| Electrical conductivity, mSm/sm | 8-9          | 8,4                                                  |
| Active acidity, pH    | 4,0-5,3             | 4,5                                                  |
| Titratable acidity, °T | 50-85              | 69                                                  |

3. Research methods
Sample taking for analysis was performed according to State Standard GOST 26809-86 [9] into sterile containers with a volume of 300 ml. After that, analyses were carried out to determine the amino acid composition in the samples based on the MVI-02-2002 method (gas chromatography measuring method, gas chromatography with a flame ionization detector, with a mass concentration of acrolein in the working zone air).

The whey nanoconcentrate was obtained on an experimental nanofiltration unit (figure 1). Curd whey, pre-cleaned from protein dust and preheated to 400°C, was fed to the product tank 1, with the valve 12 in the closed position and the valve 11 in the open position. After switching on the pump 10, the whey was circulated through the nanofiltration module. The pressure in the unit was gradually raised to 2.0 MPa with the needle valve 4, the pressure in the unit was measured with manometers 5, 8, the temperature was measured with a thermometer 3. The separation of the whey took place in the membrane module 7, after which the concentrate returned to the product tank 1, and the filtrate was drawn away through the flowmeter 6. The unit also allows maintaining the set temperature in the heat exchanger 2. The process went on until the end of the filtrate separation.
Figure 1. Scheme of an experimental nanofiltration unit
1 – product tank; 2 – heat exchanger; 3 – thermometer; 4 – needle valve; 5,8 – manometers; 6 – flowmeter; 7 – membrane module; 9 – safety valve; 10 – pump; 11,12 – manual valve.

The characteristics of the experimental unit are shown in table 2.

Table 2. Characteristics of the experimental nanofiltration unit

| Nanofiltration membrane: |  |
|--------------------------|---|
| producer                 | Vladipor |
| material                 | Polipiterazinamid |
| brand                    | PH 33 H |
| pressure P, bar          | ≤ 25 |
| temperature, °C          | ≤ 40 |
| active area S, m²         | 2 |

| Nanofiltration module:  |  |
|-------------------------|---|
| tank volume, V          | 50 l |
| pump                    | CAT PUMP, 311 |
| power                   | 2,2 kW |
| flow rate               | 900 l/h |

4. Results and discussions

The obtained data on the essential amino acids content in natural curd whey and its nanoconcentrate are shown in table 3.
Table 3. Essential amino acids content in natural curd whey and its nanoconcentrate, mg/100 g of the product

| Amino acid     | Content, mg/100 g of the product | Curd whey | Curd whey nanoconcentrate |
|----------------|----------------------------------|-----------|---------------------------|
| Valine         | 18±0,6                           | 76±2,3    |
| Isoleucine     | 55±1,7                           | 241±7,5   |
| Leucine        | 27±0,8                           | 86±2,6    |
| Lysine         | 25±0,9                           | 79±2,3    |
| Methionine     | 0,4±0,1                          | 14±0,4    |
| Tyrosine       | 12±0,4                           | 39±1,1    |
| Threonine      | 18±0,6                           | 57±1,7    |
| Phenylalanine  | 10±0,3                           | 34±1      |
| Cystine        | 0,4±0,1                          | 14±0,4    |

The results of calculating the score of essential amino acids in whey and nanoconcentrate are given in table 4.

Table 4. The score of essential amino acids in natural curd whey and its nanoconcentrate

| Amino acid     | FAO/WHO scale, g/100 g | Curd whey | Curd whey nanoconcentrate |
|----------------|------------------------|-----------|---------------------------|
|                | Content, \( A_j \) g/100g protein | \( C_j \), score, % | Content, \( A_j \) g/100g protein | \( C_j \), score, % |
| Valine         | 5                      | 4         | 80                        | 5,4           | 108                        |
| Isoleucine     | 4                      | 12,2      | 305                       | 17,2          | 430                        |
| Leucine        | 7                      | 6         | 85,7                      | 6,1           | 87,1                       |
| Lysine         | 5,5                    | 5,6       | 102                       | 5,7           | 104                       |
| Methionine     | 3,5                    | 0,9       | 25,7                      | 1             | 28,6                       |
| Tyrosine       | 6                      | 2,7       | 45                        | 2,8           | 46,7                       |
| Threonine      | 4                      | 4         | 100                       | 4,1           | 103                       |
| Phenylalanine  | 6                      | 2,2       | 36,7                      | 2,4           | 40                         |
| Cystine        | 3,5                    | 0,9       | 25,7                      | 1             | 28,6                       |

As it is demonstrated in table 4 that the limiting amino acids in whey and curd whey nanoconcentrate are methionine and cystine.

Based on the data obtained, biological value indicators were calculated using the method [10, 11] (table 5).
Table 5. Biological value indicators in natural curd whey and its nanoconcentrate

| Index                                | Index marking | Curd whey | Curd whey nanoconcentrate |
|--------------------------------------|---------------|-----------|---------------------------|
| 1 Essential amino acids index        | EAA index     | 0,658     | 0,739                     |
| 2 Utility ratio                      | UR of all AAC | 0,253     | 0,284                     |
| 3 Comparable redundancy index        | $\sigma$      | 105,31    | 115,29                    |

Determining the essential amino acids index (EAA index) allows to consider the content of all essential amino acids in the product.

As it is shown in table 5, the number of essential amino acids in the nanoconcentrate increases compared to natural curd whey.

The utility ratio of all amino acid composition (UR of all AAC) is a numerical characteristic showing the balance of essential amino acids in relation to the standard and their complete utilization. As it is demonstrated in table 5, the higher balance of essential amino acids in whey concentrate in relation to natural curd whey is proved.

The comparable redundancy index shows the total mass of essential amino acids that are not used by the body for anabolic purposes in the protein of natural curd whey and its concentrate, equal to the same amount of potentially metabolizable content of 100g of ideal protein.

The comparable redundancy index in whey concentrate is higher. This means that essential amino acids of the concentrate are mostly not used (not digested) by the body in metabolic processes.

5. Conclusion

In this work the analysis of amino acid composition of natural whey and its nanoconcentrate was undertaken. The total content of essential amino acids was identified and limiting amino acids were revealed. This information should be considered when preparing diets and developing new types of products having increased biological value.

References

[1] *Expert-analytical center of agribusiness*. Available at: https://ab-centre.ru/news/o-proizvodstvе-syrov-i-tvoroga-v-rossii-v-2018-2019-gg?

[2] Boyeva N D 2017 Problems of dairy industry *Dairy industry* 5 4

[3] Antipov S T, Ovsyannikov V Yu and Korchinskiy A A 2018 Study of blood concentration in cattle *Bul. of Voronezh State University of Engineering Technology* 80 (2) 11-17

[4] Shutro R V, Shevchuk V B, Kulenko V G and Slavorosova E V 2018 Improvement of the process of curd whey concentration by nanofiltration *Dairy Bulletin* 2 (30) 122-129

[5] Shevchuk V B, Shokhalov V A, Shutro R V, Fialkova E A and Kulenko V G 2017 Prospects for implementing resource-saving technologies in dairy industry in the context of import substitution *Innovations in the technology of healthy foods: IV Intern. science. Conf. V international. Balt. pestilence.forum: materials: sat. nauch. tr. ed. I M Titova (Kaliningrad) pp 56-60

[6] Ponomaryov A N, Melnikova E I and Bogdanova E V 2018 Whey as a raw material resource for the production of food ingredients *Dairy industry* 7 38-39

[7] Khramtsov A G and Nesterenko P G 2004 *Technology of dairy products* (Moscow: Deliprint publishing house)

[8] Lobanov V G, Kas’yanov G I and Mazurenko E A 2019 Features of the nutrition regime of the
game sports athletes *Vestnik of Voronezh State University of Engineering Technology* **81** (1) 160-167

[9] *Internet and law.* Available at: http://www.internet-law.ru/gosts/gost/19906

[10] Lisin P A, Moliboga E A, Kanushina Yu A and Smirnova E A 2012 Evaluation of the amino acid composition of a prescription mixture of foodstuffs *Agrarian Bulletin of the Urals* **3** (95) 26-28

[11] Lisin P A, Musina O N, Kister I V and Chernopol’skaya N L 2013 Methodology for evaluating the balance of amino acid composition in multicomponent foods *Bulletin of Omsk State Agrarian University* **3**(11) 53-58