Whey centralized processing of as an environmental aspect of regional development

Na Zhang¹, Vladimir Lazarev², and Tatyana Shestakova²

¹College of Food Engineering, HarbinUniversity of Commerce, Harbin Song BeiXue-Hai Street, District No. 1, Harbin, China

²Ural State University of Economics, 8th of March Street, 62, 620144 Ekaterinburg, Russia

Abstract. The article presents the practicability of developing the environmental aspect of dairy industry enterprises on the example of Sverdlovsk region. The volume of milk and cottage cheese production at the enterprises of the Sverdlovsk region is presented. The article describes the negative impact of milk processing enterprises on the environment. Statistical data on the percentage of enterprises that process secondary dairy raw materials are provided. The article presents the costs of installing local wastewater treatment plants and the rationality of creating a specialized enterprise for complex processing of whey on the basis of OJSC "Irbis Dairy Plant". The article describes the value of secondary dairy raw materials that cause the greatest harm to the environment in case of unfair whey utilization, as a raw material for the production of competitive products. The technology for processing whey at a specialized enterprise using membrane methods is presented: nanofiltration — ultrafiltration — reverse osmosis followed by vacuum evaporation and spray drying. The expediency of introducing an ultrafiltration unit with the use of ceramic ultrafiltration element (CUFE) (0.01) ceramic membranes into the line for processing whey at the OJSC Irbis dairy plant is described. The content of the main components of curd whey at all stages of production, as well as the final products, is presented. The parameters of the described processes of whey processing are given.

1 Introduction

The Sverdlovsk region of the Russian Federation is a part of the large macro-region, that of the Ural Federal district. About 28 milk processing enterprises operate here. According to the SPARK database, four of these enterprises are large ones, six enterprises are medium-sized ones, eight enterprises are small ones and ten enterprises are micro-enterprises. The volume of milk production in the Sverdlovsk region from January up to March 2020 compared to the same period of last year has increased by 8.1% and amounted up to 159.6 thousand tons. In 2019, according to the statistics from the Ministry of Agriculture and Consumer Market of the Sverdlovsk region, the regional farmers exceeded all-Russian indicators and achieved an increase in production by 4.8%. At the same time, two organizations of the Sverdlovsk region entered the top 50 of the national rating of raw milk producers: APC "Kilachevsky" took the 20th place, PJSC "Kamenskoe" took the 36th place. The Sverdlovsk region occupies the leading 6th place in the rating of 30 leading

regions in milk production in the agricultural sector as of April 1, 2020 and the 4th place in the production of cottage cheese, which amounted to 21.5 thousand tons [1].

According to the technology of production of granular cottage cheese, the output of cottage cheese is only 1/10 of the raw material, the rest is curd whey, processing of which is a labor, intensive and energy-consuming process. According to statistics from the International Dairy Association, only 20% of secondary dairy raw materials, whey, are processed in the Russian Federation, and 80% are drained into the water bodies, causing damage to the environment and the water basin. Whey contains a large amount of protein and carbohydrates, which are destroyed when exposed to environmental factors and create persistent organic pollution of territories. Studies conducted in the field of environmental protection show that for complete oxidation of 100 ml of whey, 500 ml of oxygen is required, therefore, when it enters water bodies, the percentage of oxygen in the water decreases significantly, which leads to the death of the flora and fauna of the reservoir [1]. In addition, in 2019, a law came into force that assigned milk processing enterprises to the same class of environmental hazards as metallurgical and chemical plants. According to Soyuzmolok statistics, today less than 30% of dairies have their own treatment facilities, of which only 2% are able to provide a sufficient level of wastewater treatment. Most of the dairy industry enterprises cannot actually comply with the established requirements for biological contamination and will compensate water utilities for the additional costs of their post-treatment. The cost of local full-cycle treatment facilities construction is estimated at 200 to 400 million rubles [6].

At the same time, whey is a valuable secondary raw material resource and contains about 1% animal protein, 9% lactose, some fat and minerals, and is rich in interchangeable and essential amino acids. Whey is used in the production of dairy products, meat products, diabetic, children's and sports products [2].

Analyzing the global experience of the environmental aspect of dairy processing enterprises, it can be noted that, for example, a major European dairy manufacturer ArlaFoods has installed a system for processing whey and the company has recently introduced carbonated protein water specifically for athletes, which is made from whey hydrolysate. By 2020, the company has set for itself deep processing of serum as one of the 4 main development focuses. Another example is the American leader in the Greek yogurt segment Chobani in 2014 installed a reverse osmosis unit at its plant in Idaho. Commenting on their decision, the company noted that in this way they invest in the sustainable development of agriculture [7].

The experience of complex processing of secondary dairy raw materials described above can be successfully applied to milk processing enterprises of the Sverdlovsk region. The need for whey in various areas of the food industry, as well as the need to develop the environmental aspect of dairy enterprises and reduce the negative impact on the environment, makes it advisable to process it and create a specialized enterprise with the operation of high-tech equipment, as well as the use of innovative waste-free technologies. The advantages of organizing a specialized enterprise are cost reduction in comparison with the introduction of treatment facilities, with the introduction of local processing plants for each milk processing enterprise, and savings in production space [9].

It is rational to place a specialized enterprise for complex processing of whey at the intersection of transport hubs and interchanges. Large milk processing enterprises of the Sverdlovsk region are located in the cities of Yekaterinburg, VerkhnyayaPyshma, Alapaevsk, Kushva, Talitsa and Irbit. OJSC "Irbit Dairy Factory" at the moment has already implemented the technology for processing the whey formed in the production of cheese. The plant has installed and put into operation the equipment for electric dialysis of whey for deeper processing. The technological process consists of collecting and cleaning curd whey from protein dust and fat. Using the nanofiltration unit, it is condensed and then

demineralized to the required degree of 50% in the reactor of the electrodialysis unit. Then this serum is sent to drying, and then sold.

Thus, it is proposed to organize a specialized enterprise for complex processing of whey on the basis of OJSC "Irbis Dairy Plant". The duration of serum delivery from any of these points does not exceed 4 hours. According to GOST R 53438-2009 "Milk whey. Technical conditions" milk whey must be processed within 24 hours of its receipt. At the same time, its storage temperature should not exceed 6 °C. Whey must be transported in insulated vehicles with a constant temperature of 0 to 6 ° [10].

2 Methods and Materials

GOST R 53438-2009. Milk whey. Technical conditions. It was used to establish compliance of curd whey with regulatory documents.

According to GOST 3624-92 "Milk and dairy products. Titrimetric methods for determining acidity" there were tests in the laboratory of the Ural State University of Economics to determine the acidity of curd whey. In this case, a method using a phenolphthalein indicator was used. This method is based on neutralizing the acids contained in the product with a solution of sodium hydroxide in the presence of a phenolphthalein indicator.

GOST 3626-73 Milk and dairy products. Methods for determining moisture and dry matter used to determine the mass fraction of moisture used in accordance with GOST 23327-98 Milk and dairy products. The Kjeldahl method for measuring the mass fraction of total nitrogen and determining the mass fraction of protein was used to determine the mass fraction of protein.

GOST R 51259-99. Milk and dairy products. The method for determining lactose and galactose was used to determine lactose.

GOST 5867-90 Milk and dairy products. Methods for determining fat was used to determine the mass fraction of fat.

The mass fraction of trace elements of mineral substances was determined using atomic absorption spectrophotometry on the U-2900 Hitachi device.

Studies on the content of the main components, such as protein, lactose, fat, minerals and dry substances were conducted in Uraltest, Yekaterinburg, and microbiological indicators were determined in the sanitary and epidermological service of Yekaterinburg.

3 Results and Discussions

Today there are quite a lot of methods for whey processing, but it is most advisable to concentrate it using membrane methods [1; 9]. Based on the analysis of existing methods, and taking into account the already implemented line for processing curd whey, it is offered to concentrate it according to the technological scheme shown in Figure 1.

The production technology of whey protein concentrate includes four stages: nanofiltration (NF), ultrafiltration (UF), vacuum-evaporation and drying. It is offered to obtain lactose powder using nanofiltration and reverse osmosis (RO) units, followed by spray drying [3].

The mass fractions of protein and lactose, dry matter content, and temperature are controlled in the initial curd whey and intermediate products.

At the first stage – nanofiltration, the serum is demineralized to 30%. The products after nanofiltration are a concentrate of high-molecular components (protein and lactose) and an aqueous solution with salts [4].

The second stage, ultrafiltration, involves the separation of the NF concentrate into an aqueous solution of lactose and a concentrate of high-molecular components (protein and amino acids). At this stage, the lactose is not concentrated and an equal volume is divided between the UF concentrate and UF permeate. At the ultrafiltration stage, it is proposed to use membranes with the following characteristics: average permeability of 70 l/(m²•h), protein selectivity of 0.96±0.05, which do not require preliminary separation of raw materials. Such characteristics are possessed, for example, by ceramic membranes CUFE (0.01), their advantages also include production in Russia (Moscow) and a service life of 3 to 5 years [1; 5].

The third stage, vacuum evaporation, involves thickening the UV concentrate to a dry matter content of 50%, and then, the fourth stage, spray drying, means drying matter content of 96%. During evaporation, the process temperature does not exceed 60 °C, due to which protein denaturation does not occur [1; 7]. Spray drying is carried out at an air temperature at the inlet it is 140 °C, at the outlet it is 70-80 °C, the product temperature at the outlet is 50-60 °C, which also ensures the nativity of proteins, with duration of 15-30 s.

The fifth stage, reverse osmosis, involves the separation of a mixture of UV permeate and NF permeate into a concentrated aqueous solution of lactose and industrial water. After each stage of whey processing, quality control of intermediate and final products is carried out. The results are shown in Table 1.

Fig. 1.Technological scheme for processing curd whey at a specialized enterprise for complex processing

Table 1.The content of curd whey main components produced by A.V. Anikiev Peasant Farming and intermediate products of each stage of its processing

Product	Massfraction, %					Acidity, T
	dry matter	protein	lactose	fat	mineralsubstance	
The original whey	6,30±0,42 (no less than 5,5)*	0,90±0,15	4,30±0,02 (no less than 3,5)*	0,40±0,05	0,70±0,05	70 (no more than 70)*
NF concentrate	25,38±0,42	3,19±0,15	18,56±0,02	1,68±0,05	1,95±0,05	
UFconcentrate	70,65±0,42	30,13±0,15	20,39±0,02	14,28±0,05	5,85±0,05	65
UF permeate	20,49±0,42	0,03±0,15	19,21±0,02	-	1,25±0,05	47
RO concentrate	18,07±0,42	0,04±0,15	18,03±0,02	-	-	
RO permeate	0,125±0,42	-	0,125±0,02	-	-	

* According toGOSTR 53438-2009

The raw material used was curd whey produced by A.V. Anikiev Peasant Farming (Polevskoy, Sverdlovsk region). The mass fractions of components contained in curd whey were determined by calculation based on data obtained during earlier studies on the concentration of curd whey in an ultrafiltration unit using ceramic CUFE membranes(0,01) [1; 8; 9]. As can be seen from the table above, the initial serum contains about 1% protein and 4% lactose. The degree of concentration at the nanofiltration stage for the components of whey, such as protein, lactose, minerals and fat reaches 4 times. At this stage, up to 30% of the salt is removed. At the next stage, ultrafiltration, the degree of concentration for protein reaches 10, for lactose — 5, for fat — 3, for minerals — 2.

The final product, 96%-whey protein concentrate, after spray drying has the following parameters: the temperature is 20±5 °C, the acidity is no more than 33 °T, mass the fraction of dry substances is no less than 96 %, the lactose is no less than 15 %, the protein is no less than 80 %.

During reverse osmosis, which is supplied with UV permeate and NF permeate, the lactose is concentrated 4-5 times. The final product of this stage is the RO concentrate, which is sent to the evaporation and then spray drying. The main product after reverse osmosis is lactose powder, and the secondary product is industrial water, which can be used for production purposes.

4 Conclusions

OJSC Irbit Dairy Plant can serve as a base one to createthere an enterprise for complex whey produced processing at large enterprises of Yekaterinburg, Verkhnyaya Pyshma, Polevskoy, Talitsa, Kushva and Alapaevsk. It will develop the environmental aspect of the dairy industry in the Sverdlovsk region and reduce the negative impact on the water basin of the region and the world as a whole. Due to the introduction of waste-free technology for whey processing, dairy enterprises do not need to install local treatment plants and pay fines for unfair treatment of the environment.

The final products of whey processing such as whey protein concentrate and lactose powder have a valuable composition and will be in demand in various areas of the food

industry. Adding an ultrafiltration unit to the existing line will reduce drying costs by reducing the volume of whey supplied to the unit.

The technological scheme of centralized complex processing of curd whey is represented by five stages: nanofiltration, ultrafiltration, reverse osmosis, vacuum evaporation and spray drying.

At the stage of ultrafiltration, it is advisable to use ceramic membranes CUFE (0.01) produced in Moscow or their analogues in terms of technical characteristics.

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