The analysis of flotation whey treatment

E P Evseev1,2, I V Zhuravleva3, D M Isaenko2
1OOO IF "MELN", Voronezh, Russia
2Department of Hydraulics, Water Supply and Sanitation, Voronezh State Technical
University, 84, 20-letiya Oktyabrya, Voronezh 394006, Russia
E-mail: epevseev@gmail.com

Abstract. The empirical analysis of the scheme of whey treatment was carried out. Controlled
parameters for the further investigations and assessment criteria of effectiveness of whey
treatment have been singled out: the best conditions for protein coagulation, intensity of
flocculation, the choice of the facility capable of effective working with high temperature of
waste water and flocculant application contributing to formation of the larger flakes and
process intensity. Real-time experiment on dairy enterprise LLC “SCHUCHINSKY CHEESE
MANUFACTURE” was carried out. The following equipment was applied in the experiment:
electroflotator, screw dehydrator, pump assemblies, containers for preparation of reagents and
whey heating, measuring equipment: pH-meter, flowmeter, thermometer, photometric analyzer
of chemical oxygen consumption (COC), scales. In the process of the experiment on the plants
we determined the data of COC, pH and mass of emitting protein depending on the type of the
flocculants used: superfloc A-130 and praestol 2530. The results of the experiment with whey
treatment with COC equal to more than 10000 mg/l revealed high effectiveness of high charge
anionic flocculants. New innovative technology of separate whey treatment in the
technological process of dairy factories without its discharge to waste water is presented.

1. Introduction
In the process of dairy production the output of milk whey is about 90% [1,2]. Milk whey is a by-
product of energy influence of biotechnology or molecular-sieving filtration on milk [3,4]. In the
process of manufacture milk whey is discharged to drain as its processing is energy-consuming. World
amount of milk whey discharged to drain is around 50 % of the total output [5]. In Russia the figure is
80%. “According to D.I. Mendeleev Institute for Metrology (VNIIM), about 30% of dairy enterprises
have no wastewater treatment. Due to lack of financial support the technological equipment base is
renewed per less than 3-4% a year, that reveals the continuing process of ageing of the active part of
production assets. The share of the main technological equipment satisfying modern requirements, is
less than 12%” [6].

2. Research problem statement and theoretical part
The discharged water in dairy enterprises contains curd and cheese whey, physical-and-chemical
methods known today are not effective enough to treat waste water to comply with regulations. As a
rule these methods are used to target treatment of discharged water with 1500-3500 mg/l of COC
contents [7]. COC of waste water containing milk whey, however, is over 10000 mg/l. It is caused by
the fact that in the production of cheese, curd and similar products the temperature of the discharged
whey is 30°C that serves as the environment for the microorganisms and pathogenic microflora development [8, 9]. Thus, more effective methods of such water treatment are required.

“When the usual methods of treatment are applied, in particular, pressure flotation, the temperature of waste water must be significantly lowered, because the method based on dissolving gas in water under pressure at high temperature of treated water basically doesn’t work, as when the temperature of water rises the solubility of gas sharply drops to zero when approaching boiling point” [10].

“It was found out that there is a direct dependency between the indicators of COC and BCOfull (biochemical consumption of oxygen) for waste water of dairy enterprises: BCOfull (0,80÷0,84) COC” [11,12]. “The ratio between BCOfull and COC characterizes the ability of waste water admixtures to biochemically oxidize”. In production of cheese and curd whey is acidic. In the enterprises where the technology of milk fermentation isn’t used pH parameter of waste water is close to the neutral point [13].

In these difficult conditions we aim to find a solution for the compact scheme of treatment meeting the needs of the time - “The lowest cost with maximum efficiency” [14].

3. Conducting an experiment

To reduce costs it was proposed not to mix whey with waste water, as extraction of dissolved protein is a more difficult process than its separate treatment.

The basic categories of whey treatment effectiveness are listed below:
- protein denaturation (coagulation) when heated up to optimal heat exposure allowing maximum extraction of protein compounds which corresponds to the temperature of 95°C [15];
- intensification of the process of flakes formation with neutral pH [16], as the charge of the proteins reaches zero (its isoelectric point);
- use of the equipment effectively working on heated liquids. This can be performed by electroflotator [17];
- acceleration of aggregation of pollution particles into the larger ones and intensification of the process of particle capture, their fixation on small gas bubbles and creation of conditions for the active foam formation. Addition of flocculants will allow to achieve the above conditions during the process of electroflootation.

To conduct the experiment in real conditions, we used the following equipment and materials:
- electroflotator [17] - apparatus for processing of purified liquids;
- screw dehydrator - plant for processing of floatable sludge;
- pumping plants for pumping liquids;
- plants and containers for preparation of solutions of flocculant and alkali;
- flocculants: superfloc A-130, praestol 2530, praestol 853, and alkali NaOH in the form of solutions;
- container for heating whey, pipelines and valves;
- measuring instruments: pH meter, flow meter, thermometer, COC photometric analyzer, scales.

Technical equipment, plants and containers were selected in accordance with the calculation of the known data.

The experiment was carried out in real conditions at the dairy enterprise LLC ‘SCHUCHINSKY CHEESE MANUFACTURE’. Figures 1-5 show the installation of the electroflotator, equipment and auxiliary containers, on which the experiments were carried out.

4. Research results

During the experiments on the plants, the COC values, pH and the mass of the protein secreted were determined depending on the type of flocculant used: superfloc A-130 or praestol 2530. The table shows the results of processing whey using these flocculants.
Adding reagents gives the following results:
1. contaminant particles aggregate into the larger flocs;
2. intensifies the capture of particles and contributes to their fixation on gas bubbles, less protein is required for associated protein;
3. leads to intensification of foam formation.

It is known that proteins in whey are in a dissolved state. Their capture is a complex process [18, 19]. In the proposed whey treatment scheme, heating was used in the first step to extract the proteins. In the process of heating, the protein begins to curl up, turning into a creamy-coloured flake. Protein coagulation is a consequence of denaturation [20]. The secondary, tertiary and quaternary structure of the molecule changes in the process of denaturation. “The protein globule is unfolding in the process
of denaturation. The process is accompanied by a change in the configuration, hydration, and aggregative state of the particles. The protein globule becomes less stable during denaturation” [7].

Figure 5. Electroflotator collecting container.

Table 1. The results of the processing whey using these anionic flocculants Superfloc A-130 and Praestol 2530.

| The investigated parameters | Initial parameter values | Final values after cleaning on an electroflotator | Cleaning efficiency, % | The mass of extracted protein, g/l |
|-----------------------------|--------------------------|-----------------------------------------------|------------------------|-----------------------------------|
|                            |                          | praestol 2530 | superfloc A-130 | praestol 2530 | superfloc A-130 | praestol 2530 | superfloc A-130 |
| pH                         | 4.2                      | 6.5          | 6.5               | 98          | 99                 | 3.8          | 4.0                   |
| COD, mg/l                  | 18000                    | 340          | 180               | 80          | 84                 | 2.1          | 2.5                   |
| pH                         | 4.3                      | 6.1          | 6.1               | 78          | 83                 | 2.0          | 2.3                   |
| COD, mg/l                  | 12000                    | 2400         | 1920              |             |                    |              |                       |
| pH                         | 4.3                      | 5.8          | 5.8               |             |                    |              |                       |
| COD, mg/l                  | 12000                    | 2600         | 2040              |             |                    |              |                       |

In the process of denaturation, the following changes in protein occur:

1. the biological activity of the protein is reduced;
2. the physical properties of the protein change;
3. the protein loses its ability to dissolve and swell;
4. the reactivity of the protein increases;
5. the protein is better subjected to enzymatic action.

With a longer heating time and high temperature, denaturation increases. “It was established that the threshold for whey protein denaturation is at 50-65 °C, visible coagulation is observed at 75-80 °C, and the optimum thermal effect corresponds to 90-95 °C” [7].

Our studies have confirmed these points and have led to high whey processing efficiencies.

The isoelectric point of the protein is that pH medium at which the total charge of the proteins is zero, i.e. protein molecules have no charge. Upon reaching the isoelectric point, proteins begin to flocculate. Before heat exposure, protein molecules have a charge on their surface. Due to the presence of a charge, proteins are in a soluble state. As soon as the protein loses its charge, it begins to flocculate and precipitate.

5. Conclusions
An innovative technology is offered for the separate collection and processing of whey of dairy enterprises, without mixing it with wastewater.

The whey treatment regimen includes:

- heating of whey up to 75 - 95 ° C;
- pH adjustment with NaOH solution;
flocculation using anionic reagents with a high charge;
- electroflotation [17] of a whey mixture with a flocculant;
- dehydration of the foam concentrate after the flotator with the addition of the cationic flocculant praestol 853. A screw dehydrator is used to dewater the flotation sludge.

The suitability of the method for whey treating with a COC value of more than 10,000 mg/l has been experimentally confirmed as well as the efficiency of protein extraction at 80 - 99% without the use of extended biological installations.

The research was implemented on dairy enterprise LLC “SCHUCHINSKY CHEESE MANUFACTURE”, located at Voronezh Region, Ertil district, Schuchye Village, Lenin Street, 1.

The extraction of whey can be included in the technological process of processing dairy products with further use in food products.

References
[1] Tetra Pak 2010 Directory - Dairy Production Technology Pasteurized Dairy Products Part 1
[2] Perevozchikov A, Kabanova T 2006 General technology of the dairy industry (Yoshkar-Ola: Mari State University) p 83
[3] Kruš G, Kramtsov A, Volokitina Z and Karpychev S 2006 Technology of milk and dairy products Ed A Shalyginoy (Moscow: Kolos) p 455
[4] Alekseenko A, Girilovich I and Gapeeva T 2006 Technology of milk and dairy products (Mogilev: MGUP) p 31
[5] Vozhdaeva L and Kotova T 2006 General technology of the dairy industry (Kemerovo: Kemerovo Institute of Food Technology) p 160
[6] Lakomova R 2010 Milk whey in Russia: processing problems and market prospects (Moscow: consulting Abercadc) Industrial Market Research: Biotechnology 6 p 2
[7] Evseev E, Babkin V, Nenno V, Seydaliev G, Stupin V and Chubirko M 2010 Analysis of local wastewater treatment methods Production ecology 10 73–77
[8] Kruš G, Tinyakov V and Fofanov Yu 1986 Milk technology and equipment for dairy enterprises (Moscow: Arropromizdat) p 280
[9] Bredikhin S, Kosmodemyansky Yu and Yurin V 2003 Technology and equipment for milk processing (Moscow: Kolos) p 400
[10] Epov A and Kanunnikova M 2015 Wastewater treatment of agricultural enterprises NDT 1 52–56
[11] Shifrin S, Ivanov G, Mishukov B and Feofanov Yu 1981 Wastewater treatment of meat and dairy industry enterprises (Moscow: Light and food industry) p 272
[12] Kramtsov A and Nesterenko P 1989 Non-waste technology in the dairy industry (Moscow: Agropromizdat) p 279
[13] Valiullina D and Kusova I 2017 Wastewater of the dairy industry New science: problems and prospects T 1, 2 61–64
[14] Zhuravleva I 2011 Reconstruction of engineering services and water supply and water disposal facilities (Voronezh: Voronezh State University of Architecture and Civil Engin.) p 146
[15] Kramtsov A, Pavlov V, Nesterenko P and et al. 1989 Processing and use of milk whey Technological notebook (Moscow: Rosagropromizdat) p 271
[16] Chukhno A, Dmitriev I and Martynov D 2011 The isoelectric point of proteins in aqueous azoles Journal of St. Petersburg University 2 124–133
[17] Evseev E 2018 Device for electroflotation treatment of aqueous solutions (patent for invention) p 3
[18] Tikhomirova N A 2007 Technology and organization of milk and dairy products manufacturing (Moscow: DeLi print) p 560
[19] Chekulaeva L and Golubeva L 2002 Technology for preserving milk and dairy products Textbook for high schools (Moscow: DeLi print) p 249
[20] Ryazantsev E, Dmitriev M and Bershova T 2005 Food Denaturation Food industry 9 90–91