Studii şi Cercetări Ştiinţifice 2016, **17** (3), pp. 239 – 247
Chimie şi Inginerie Chimică, Biotehnologii, Industrie Alimentară

Scientific Study & Research
Chemistry & Chemical Engineering, Biotechnology, Food Industry **ISSN 1582-540X**

ORIGINAL RESEARCH PAPER

ISOLATION OF PROTEIN MINERAL CONCENTRATES AT ELECTROPHYSICAL PROCESSING OF WHEY IN STATIONARY REGIME

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Received: June, 15, 2016
Accepted: September, 09, 2016

Abstract: The paper deals with the study of isolation of protein mineral concentrates at the electrophysical processing of whey, which is practically important for food industry, as one. In the focus of attention were variations of the: electric current strength, energy consumption, *p*H values, and the degree of the isolations of proteins at different current densities. As a result, the optimal degree of the isolation of proteins at the stationary regime was determined, which heavily depends on the primary processing of milk as well as on the solid matter content and protein of the initial whey.

Keywords: *ecologically friendly, energy consumption, membrane electrolyser, oxidation-reduction potential, pH value, type of whey*

INTRODUCTION

Currently the development of ecologically friendly, waste less technologies and approaches for their implementation has received a special attention in several areas. One of them, of a primary importance for humans, is food industry, for example, processing of dairy food and obtaining its by-products which often generate problems for the environment. This is why today there is an intensive process of revising environmental requirements concerning various kinds of wastes. Development of waste less technologies and processing of whey in a closed cycle is one of the major global challenges [1, 2]. Milk owes its nutritive values to the milk sugar – lactose (a disaccharide sugar found only in milk, which during primary milk processing almost completely passes into whey, making up 70 - 80 % of its solid matter content, depending on the primary processing mode; and it can isomerize into lactulose [3]. Then, also to nitrogen from protein fractions, and to an impressive content of calcium that is extremely beneficial for the human skeletal system, all those and other milk ingredients making up a vital biologically active base for a human body. First of all, these vital for men substances are in the dairy by-products isolated after primary milk processing. Skim milk, buttermilk, and whey are main lactic by-products that should be rationally and entirely consumed. The mode of the primary milk processing results in two types of whey: sweet (*p*H 5.5 - 6.0, manufactured when making several types of hard cheese) and acid/sour (*p*H 4.5 - 5.1), produced when making acid types of dairy products such as cottage cheese or curd products. When using non-standard high technologies for isolation of proteins from milk, an ultra-filtrate is formed, also considered a dairy by-product. The solid matter content of whey is 6 - 8 %, which makes about 50 - 70 % of that of the whole milk [4]. However, in the respective literature, the cited solids content of whey is more various and it is stated that it depends on the mode of the primary milk processing [5]. Proteins are other important components of whey composition similar to those of blood by their structure, one of their functions being immune activity [6]. Whey lipids are more dispersed than those of milk and are beneficial for the biochemical digestive processes. The mineral composition of whey is very large and is optimally balanced and varied from the biological point of view [7, 8]. There are different techniques to process dairy by-products for obtaining protein concentrates used in various food (dietary) supplements as biologically active substances and in pharmaceutical products. Of special interest is the usage of proteins isolated from whey. Still, the usage of whey proteins for the purposes mentioned requires working under certain specific strict conditions – special technological regimes to ensure a high degree of purity and maintenance of natural qualities [9]. Current situation**,** on both national and international scale, related to the development of ecologically friendly technologies for processing dairy by-products requires: the elaboration of new high-tech and efficient methods, including electro physical processing; establishment of the parameters for the process functioning; and implementing energy saving techniques for the process in question [10], without using chemical reagents, at a low temperature and a low energy consumption. The mode of a solution to this problem, which influences the advances in the area through the introduction of electrophysical techniques, is demonstrated in the present paper.

MATERIALS AND METHODS

Experimental equipment and the objects of study

The study of the electro physical processing of whey reveals the necessity of certain technical requirements in order to ensure the management and control of a technological process that takes place in an electrolyser. For simplicity, the main processes in an electrolyser can be presented as follows:

- Oxidation of water on the anode: $2H_2O - 4e^- \rightarrow 4H^+ + O_2$
- Reduction of water on the cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ [12]

An experimental diaphragm electrolyser EDP-0.5 (Figure 1) has been used to study the whey electro physical processing in laboratory conditions.

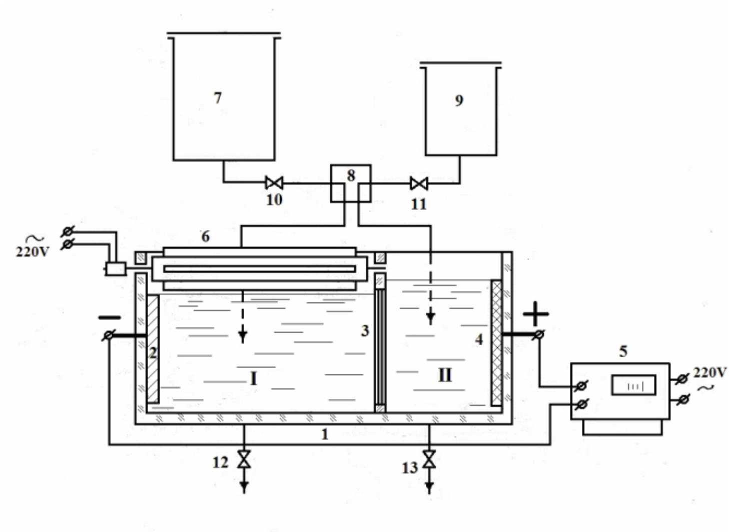

***Figure 1**. Layout of experimental diaphragm electrolyser EDP-0.5:*
I – cathode cell; II – anode cell; 1 – dielectric frame; 2 – cathode; 3 – diaphragm; 4 – graphite anode; 5 – DC power supply TEC-5020; 6 – equipment for releasing foam; 7 – container for process liquid (whey); 8 – peristaltic pump KEP-1; 9 – container for secondary liquid; 10 – valve for whey intake ; 11 – valve for secondary liquid intake; 12 – valve for release of foam formed after whey processing; 13 – valve to release secondary liquid (to be recycled later)

The diaphragm electrolyser EDP-0.5 is manufactured from transparent Plexiglass that makes it possible to follow the processing of whey (process liquid). The cathode cell (I) is separated from the anode cell (II) by a special diaphragm/membrane (3). Whey is taken from container (7) using the KEP-1 peristaltic pump (8) through the valve for whey intake (10) into the cathode cell (I). The secondary liquid is released into the anode cell (II) from container (9) through the intake valve (11).

The studies were carried out with the three types of whey provide by the Chisinau dairy factory Joint-Stock Company - JLC, the largest in the Republic of Moldova: whey after manufacture of the granulated cottage cheese „*Grăuncior*”; whey after manufacture of „*Cottage cheese*” (2 % fat content) and whey after manufacture of „*Curd product*” (18 % fat content).

The whey processing was carried out by applying the direct current to the electrodes of the electrolyser EDP-0.5: cathode (2) and anode (4), from the DC power supply TEC-5020 (5). The EDP-0.5 worked in the static regime, with a certain flow rate of the whey (process liquid), that was relieved by a peristaltic pump into the cathode cell. The secondary liquid was relieved into the anode cell. In the cathode cell, during the entire processing period, the temperature limit of the denaturation of protein fractions was controlled by a thermometer after each 5 minutes.

As a result of ionic flotation, whey in the form of foam was collected into a container in which it was stirred so as to damage the foam. In the first 5 minutes at the beginning of the processing, the value of *p*H was measured. Next, the protein-mineral concentrate (PMC) from the deproteinized whey (DW) was isolated by centrifugation at 3000 $rot\cdot min^{-1}$ (1500 G). After that, both the PMC and DW were analysed to determine certain physical-chemical and biological indicators. The secondary liquid from the anode cell was collected into a container to be later recycled.

Studies of the isolation of protein fractions at different electric current densities have been carried out at the processing of whey after the manufacture of the *„Cottage cheese”* (2 % fat content), in a stationary regime, the processing time was 30 minutes, with the registration of all parameters every 5 minutes, while varying the current density range at 8 – 24 $mA\cdot cm^{-2}$ (the pace of varying the current density was 2 $mA\cdot cm^{-2}$).

Active acidity (*p*H value) was also different at different current densities: from *p*H 4.95 - 7.30 for $j = 8\ mA\cdot cm^{-2}$ up to *p*H 4.95 - 12.25 for $j = 24\ mA\cdot cm^{-2}$.

The degree of isolation of protein fractions in the PMCs was studied at various current densities.

RESULTS AND DISCUSSION

It was found that protein fractions from serum proteins in whey have different behaviour after the isolation from the PMCs during electro physical processing. In addition, different content remaining in the cathode cell (CC) has been registered.

Proteins from whey after the manufacture of the granulated cottage cheese *„Grăuncior”* are isolated in a maximal quantity during first 5 - 10 min. (~ 52 - 57 %); they also have the lowest quantity of proteins that remained in CC, while proteins from whey after the manufacture of the *„Cottage cheese”* (2 % fat content) have the maximal isolation degree of 62 - 63 % after 25 - 30 minutes of processing, they also have a quite high quantity of proteins that remained in CC. Proteins from whey after the manufacture of the *„Curd product”* (18 % fat content) are isolated at 20 - 25 minutes maximum, and they allow for the isolation of about 42 - 43 % of serum proteins from the PMCs. The isolation of the casein powder does not influence the degree of protein isolation; still, in this case, from each type of whey, a lower quantity of proteins is isolated.

Quantitatively, the modifications of the initial protein content of three types of the whey under investigation here, before and after the isolation of casein powder, are depicted in Figure 2.

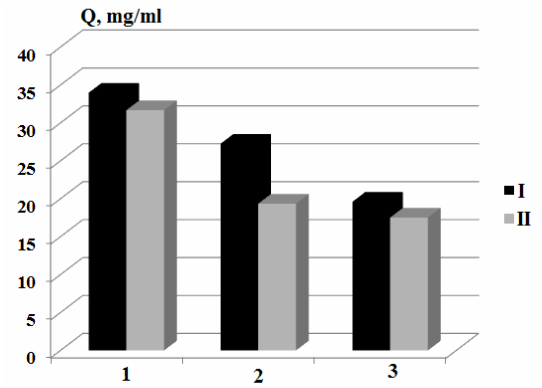

Figure 2. *Initial protein content:*
I - initial whey without isolation of casein powder; II - initial whey with isolation of casein powder;1- whey after the manufacture of the granulated cottage cheese „Grăuncior”; 2 - whey after the manufacture of the „Cottage cheese” (2 % fat content); 3 - whey after the manufacture of the „Curd product” (18 % fat content)

Characteristics of electrical parameters

The current strength was different for the three whey types investigated, depending on the initial mineral content and primary milk processing methods (Figure 3).

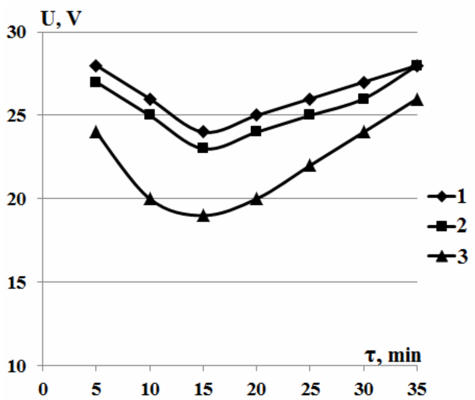

Figure 3*. Variations of electric current strength (j = 20 mA·cm^{-2}) at stationary regime, at electrophysical processing of three types of whey after manufacture of: 1. granulated cottage cheese „Grăuncior”; 2. „Cottage cheese” (2 % fat content); 3. „Curd product” (18 % fat content)*

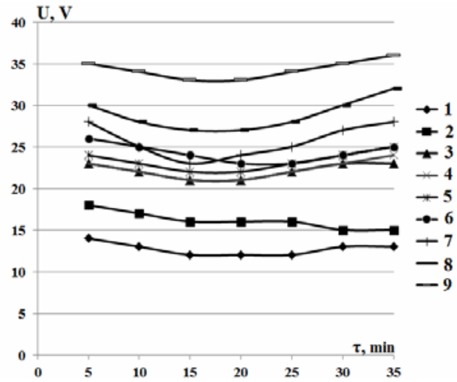

Figure 4*. Variations of electric current strength at stationary regime, at electrophysical processing of whey after manufacture of „Cottage cheese” (2 % fat content), at current densities of j: 1 - 8; 2 - 10; 3 - 12; 4 - 14; 5 - 16; 6 - 18; 7 - 20; 8 - 22; 9 - 24 mA·cm^{-2} and processing durations of τ = 5 - 30 min*

The difference in the electric current strength is characteristic for the processed medium conductivity and it varied from of 12 - 14 V for j = 8 mA·cm^{-2} up to 33 - 36 V for j = 24 mA·cm^{-2} (Figure 4). Energy consumption at the electro physical processing in the mentioned conditions (stationary regime, object of processing - whey after the manufacture of the *“Cottage cheese”* (2 % fat content), at current densities of j = 8 - 24 mA·cm^{-2} and durations of processing of τ = 5 - 35 minutes) varied and went up significantly with an increase of the current density. It happened because the energy consumption depends on the whey conductivity, which, in turn, depends on the solid matter content; on constructive/geometric parameters of an electrolyser; on the membrane type; and on the concentration and content of the secondary liquid (Figure 5). When the current density increased, the temperature of the processed whey went up dramatically, especially at j = 22 - 24 mA·cm^{-2}, the limit for the whey proteins denaturation being 55 - 65 °C (Figure 6).

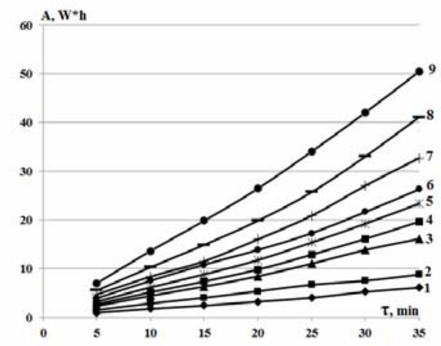

Figure 5. *Variations of energy consumption, stationary regime, at electro physical processing of whey after manufacture of „Cottage cheese" (2 % fat content), at current densities of j: 1- 8; 2- 10; 3- 12; 4 - 14; 5 - 16; 6 - 18; 7 - 20; 8 - 22; 9 - 24 mA·cm^{-2} and durations of processing of τ= 5 - 35 min*

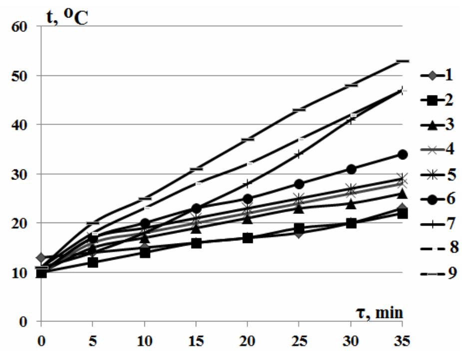

Figure 6. *Variations of temperature (stationary regime) at electro physical processing of whey after manufacture of „Cottage cheese"(2 % fat content), at current densities of j: 1- 8; 2 - 10; 3 - 12; 4 - 14; 5 - 16; 6 - 18; 7 - 20; 8 - 22; 9 - 24 mA·cm^{-2} and durations of processing of τ= 5 - 35 min*

Active acidity (*p*H value) was as follows: at j = 8 mA·cm^{-2} - *p*H was 4.95 - 7.30, and at j = 24 mA·cm^{-2} - *p*H was 4.95 - 12.25. At a quite high current density (j = 22 - 24 mA·cm^{-2}) the transformation of aqua-complexes into hydro-complexes, practically, does not exist (Figures 7 and 8).

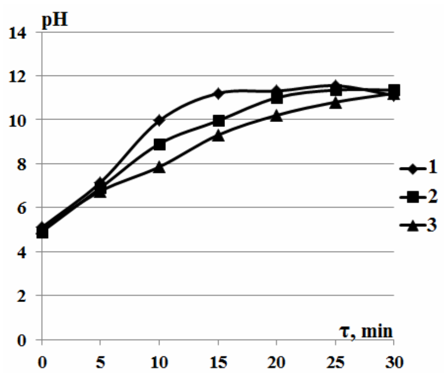

Figure 7. *Variations of pH at electro physical processing (j = 20 mA·cm^{-2}, stationary regime) of three types of whey after manufacture of: 1. granulated cottage cheese „Grăuncior"; 2. „Cottage cheese" (2 % fat content); 3. „Curd product" (18 % fat content)*

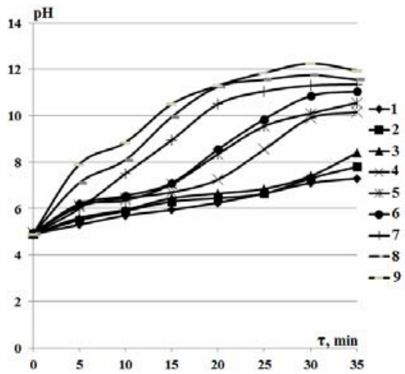

Figure 8. *Variations of pH (stationary regime) at electro physical processing of whey after manufacture of „Cottage cheese"(2 % fat content), at current densities of j: 1 - 8; 2 - 10; 3 - 12; 4 - 14; 5 - 16; 6 - 18; 7 - 20; 8 - 22; 9 - 24 mA·cm^{-2} and durations of processing of τ= 5 - 35 min*

Isolation of whey proteins

The degree of isolation of protein fractions in the PMCs varied from 8.95 - 30.55 % for j = 8 mA·cm^{-2} up to 51 - 57 % for j = 24 mA·cm^{-2}, the maximal value registered being 61 - 64 % at a current density of j = 20 mA·cm^{-2}, after processing for 20 - 25 min. at a temperature of 28 - 34 °C, but in the first 5 - 15 min, the degree of the isolation of protein fractions was 50 - 59 % at a temperature of 14 - 23 °C (Figure 9).

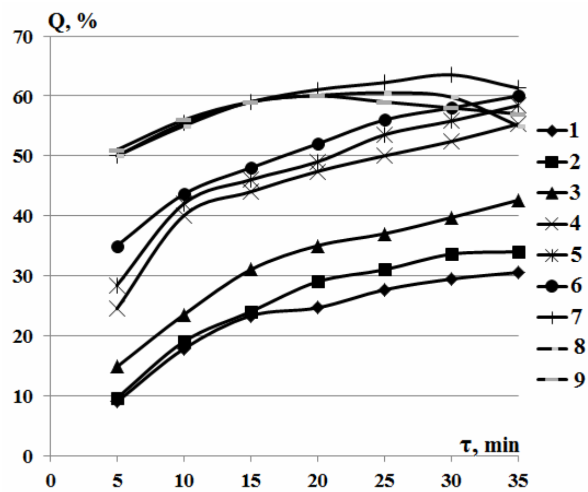

Figure 9*. Variations of degree of protein isolation from PMCs (stationary regime) at electro physical processing of whey after manufacture of „Cottage cheese" (2 % fat content), at current densities of j:*
1- 8; 2 - 10; 3 - 12; 4 - 14; 5 - 16; 6 - 18;
7 - 20; 8 - 22; 9 - 24 mA·cm^{-2} and durations of processing τ = 5 - 35 min

For the whey after the manufacture of the granulated cottage cheese *„Grăuncior"*, we have registered the maximal isolation during first 10 minutes, which tells us of a different content of initial protein fractions in this type of whey, which is different from the other two types (Figure 10). As is clear from Figures 9 and 10, the degree of the recovery of proteins in the PMCs is different for the three types of whey investigated. It can be accounted for by the following factors: variations of the primary processing of milk, of initial solid matter content of whey, as well as of that of proteins and minerals. The protein content of the whey after the manufacture of the *„Curd product"* (18 % fat content), is much lower in comparison with that of the other two types of whey; still it keeps the isolation nature in the PMCs as is also the case for the whey after the manufacture of the *„Cottage cheese"* (2 % fat content) (Figure 11).

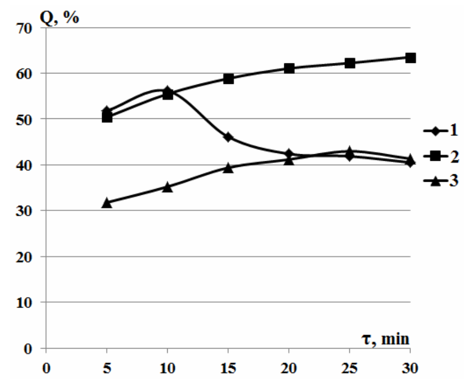

Figure 10. *Variations of degree of recovery (Q, %) of protein fractions from whey in PMCs (stationary regime) without isolation of casein powder, at processing of three types of whey after manufacture of:*
1. granulated cottage cheese „Grăuncior”;
2. „Cottage cheese” (2 % fat content);
3. „Curd product” (18 % fat content)

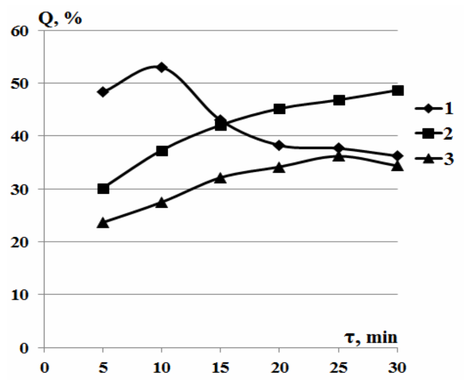

Figure 11. *Variations of degree of recovery (Q, %) of protein fractions from whey in PMCs (stationary regime) with isolation of casein powder, at electro physical processing of three types of whey after manufacture of:*
1. granulated cottage cheese „Grăuncior”;
2. „Cottage cheese” (2 % fat content);
3. „Curd product” (18 % fat content)

CONCLUSIONS

As a result of the investigations of the electro physical processing of three types of whey at a stationary regime, at current densities of 8 - 24 mA·cm^{-2}, the following was established:

1. The optimal regime of the processing of whey after manufacture of *„Cottage cheese”* (2 % fat content) is at a current density of 20 mA·cm^{-2}. It makes up about 60 % of time of 15 - 20 min., at 20 - 35 °C, which excludes the thermal denaturation of the whey protein fractions.
2. The degree of the recovery of proteins in the PMCs is different for the three types of whey investigated.
3. Variations of electric current strength, of the active acidity (*p*H), of the degree of recovery of protein fractions from whey in the PMCs are higher at high current densities.
4. The impact of the electro physical processing of the three types of whey mentioned above mostly depends on the primary milk processing and the solid matter content in the initial whey.

ACKNOWLEDGEMENTS

This research has been carried out in the framework of the STCU project #6011.

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