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# Electrical Processing of Whey. Role of Construction, Technological and Energy Characteristics of Reactors

**E. G. Vrabie[a], *, M. K. Bologa[a], I. V. Paladii[a], T. G. Stepurina[b], V. G. Vrabie[c], V. P. Goncharuk[a], A. A. Polikarpov[a], and C. G. Sprinchan[a]**

[a] *Institute of Applied Physics, Chisinau, MD-2028 Moldova*

[b] *Moldova State University, Chisinau, MD-2009 Moldova*

[c] *Institute of Physiology and Sanocreatology, Chisinau, MD-2028 Moldova*

**e-mail: vrabie657@yahoo.com*

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**Abstract**—The purpose of this work was to study the basic construction, energy, and technological features of the electrochemical reactors used in the manufacture of whey, a dairy by-product and a biologically very valuable liquid. The choice of optimal regimes for processing various types of whey was specified aimed at increasing the efficiency of the recovery of whey protein fractions in the protein–mineral concentrates through reduction of the energy consumption. It is demonstrated that features of the electric reactors must be reasonably selected, including the distances between the electrodes and between the electrodes and the membrane, as well as their geometric shape, to avoid occurrence of dead areas and to ensure a high efficiency of the process. It was also important to find the most appropriate options for electric parameters and processing regimes (periodic or continuous). In addition, the ratio of the whey volume and the main electrode area, the type of the regimes membrane, the initial content of the dry matter in each type of the whey (in particular, its protein composition), and the compositions and concentration of the anodic (secondary) liquid, were taken into account. The results of the study are significant for the development of a wasteless technology of processing the dairy by-products.

*Keywords:* electrochemical reactors, whey, protein-mineral concentrates, cathode and anode chambers, membrane, energy consumption, wasteless technology

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## INTRODUCTION

The processing of whey continues to require more and more efficient engineering and technological solutions that take into account both its rational and complete use of components and ecological sustainability connected with wasteless processing. One successful technological method is the electrical processing of whey using recovery of the protein mineral concentrate (PMC) and the simultaneous isomerization of lactose into lactulose using the electrochemical activation (ECA) of the liquid. This approach was developed in Chisinau at the Institute of Applied Physics in the second half of the 1990s [1].

To increase the efficiency of recovery of the whey proteins and decrease the specific power consumption, the choice of the reactor must be justified, and the characteristics of its construction must be taken into account, among which are the distances between the electrodes, and between the electrodes and the membrane, and the geometric shape that eliminates dead zones. All these are to ensure the high efficiency of whey processing, provided that the reactor is chosen correctly.

This study prioritized obtaining protein–whey concentrates (PWC) to be used by babies and as dietic food. When the PWC (separated in the form of a milk color sediment) is obtained, a large amount of deproteinized whey (DPW) is yielded, in which lactose is transformed into lactulose. The isomerization of lactose into lactulose, as a highly efficient process of transformation (32% of isomerization), is described in [2–5]. The experiments conducted supported the advantage of obtaining the PMC that was enriched by minerals with a simultaneous isomerization of lactose into lactulose [6–8]. A substantial contribution to the elaboration of the methods for obtainment of lactulose was made in [9–14].

The features of the electrical processing of whey, which are indicated directly after the completion of the process and during storage, i.e., the pH and oxidation-reduction potential (ORP) variations are the primary conditions for the recovery of the PMC and isomerization of lactose to lactulose [15].

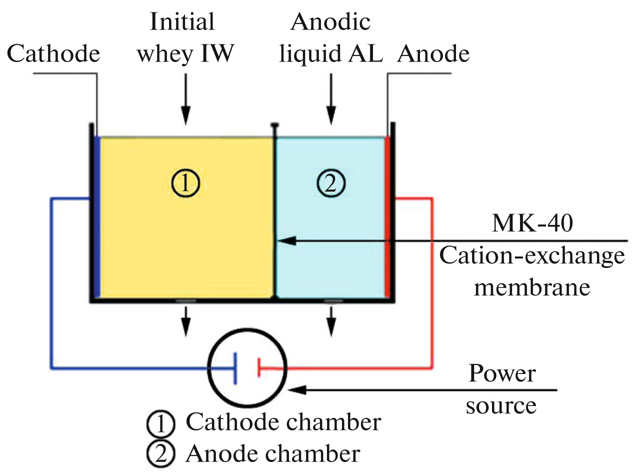


**Fig. 1.** Scheme of electrochemical reactor/electrolyzer.

The main aim of this work was to exhibit the results of studies of electrical processing of whey using the ECA, which ensures wasteless technology for obtaining the PMC with a simultaneous isomerization of lactose to lactulose, contained in the whey in different electrochemical reactors (electolyzers/electroactivators), and to justify the choice of the device for and mode of the IW processing.

Using the ECA of whey has been described in many works, e.g., in [16–28].

However, a large-scale transfer from laboratory to industrial activators requires thorough examination of the construction, technological, and energy characteristics of reactors.

The advantages of the ECA consist in its ability to bring about the entire elimination or a significant reduction of chemical reagents in the process of the activation of the water solutions meant for various purposes, as well as the elimination or sharp reduction of the necessity of purification of sewage waters. Profitability would be determined by a substantial increase in the efficiency of the technological processes both due to a decrease in labor, time, and materials consumption and a simultaneous improvement of the quality and functional properties of the final products.

The characteristics of the reactors (electrolyzers/electroactivators) are given in [25–28]. Those works have special requirements and conditions, namely, the type of the material for the cathode and anode manufacturing (the electrode material must be characterized by good electrical conductivity and have sufficient mechanical strength to maintain the initial properties through lengthy operations, and be low cost). Further, the location and form of the electrodes must ensure a uniform distribution of current density. The type of a partition (a diaphragm, membrane, and a volumetrically penetrable element), i.e., the element that divides the cavity of the reactor into anodic and cathodic zones. The main electrode must be inert and insoluble in the product and able to be used in the food industry. This work is devoted to a thorough experimental study of various reactors so as to enable a choice of optimal operation efficiency related to the process and specific energy consumption per unit of product.

## EXPERIMENTAL

To reach the above aims, the whey processing was performed in cathode chambers of membranous electrolyzers (electrochemical reactors) of six types. They were EDP-0.5; EDP-S (sectional); EDC-3; EDP-2; EDP-4 and EDP-5—slot-type, at the current densities of $j$ = 10 and 20 mA/cm$^2$. The reactor frames were made of a dielectric material, cathodes from an AISI 304/1.4301 steel (used in the industrial equipment for food, dairy, and pharmaceutical manufacture) and anodes from solid graphite (to avoid dilution); the cathode and anode chambers were separated by MK-40 heterogenous membranes (Fig. 1). The cathode and anode areas in all electrolyzers are similar.

The electrochemical reactors differ by interelectrode gaps, by the volume of the whey being processed in a cathode chamber, by the ratio between the volume and the area of the main electrode (cathode) $V/S$ (mL/cm$^2$), and by the geometry of the frame, which ensures different conditions for conductivity and activation. All electrolyzers (except for EDC-3) are made in the form of parallelepipeds with a vertically positioned cathode and anode, separated by a heterogeneous membrane. The electrolyzer used as an apparatus of the periodic and continuous action (EDC-3) is a semicylindrical frame with a cathode on it, a separating membrane, and a semicylindrical anode, which excludes nonfunctional zones (dead sections) [29]. The EDP-5 (slot-type) serves to increase the surface of activation and used as a parallelepiped with two vertical electrodes (cathode and anode) and a slot-type cathode chamber.

The EDP-0.5 and EDP-S have similar distances between the electrodes and between the electrodes and the membrane, but different ratios of whey volume to the surface of the main electrode (cathode) ($V/S$ = 5 (mL/cm$^2$) for the EDP-0.5; $V/S$ = 4 (mL/cm$^2$) for the EDP-S). Similarly the pair of electrolyzers, the EDP-2 and EDP-4 were studied, using identical distances between the electrodes and the electrodes and the membrane, but different ratios of whey volumes to the surface of the main electrode ($V/S$ = 1.4 (mL/cm$^2$) for the EDP-2, and $V/S$ = 1 (mL/cm$^2$) for the EDP-4). For the EDC-3, the ratio was $V/S$ = 2 (mL/cm$^2$), and for the EDP-5 slot-type it was $V/S$ = 0.3 (mL/cm$^2$) (Table 1). The volumetric current density $i_v$ (A/L) was measured for each electrolyzer.

The three types of the IW produced by the Chisinau JLC Dairy Plant were processed in a main chamber for the electrochemical activation (cathodic), after