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TECHNOLOGY FOR OBTAINING MILK SUGAR FROM SECONDARY MILK RAW MATERIALS

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Annotation
The rational use of secondary raw materials on the principles of resource and energy saving is one of the most urgent tasks of the food and processing industries of the agro-industrial complex. In the dairy industry, the problem of effective whey processing is traditionally most acute, in particular, the maximum extraction of dry substances (up to 50% of the initial concentration in milk) - lactose (the main carbohydrate of milk), biologically complete whey proteins, vitamins and other biogenic elements. In the last decade in foreign countries with the most developed dairy business, much attention has been paid to the directed synthesis of derivative components of dairy raw materials (primarily lactose and whey proteins), the inclusion of which in food formulations gives them additional biological value and functional properties.

Keywords: milk product, sugar, technology, method, lactose, food.

INTRODUCTION

An analysis of the current state and trends in the development of equipment and technologies for the processing of dairy raw materials [5, 7] allows us to identify the most promising areas for solving the tasks set:

– deep fractionation of milk protein-carbohydrate raw materials by baromembrane (microfiltration, ultrafiltration, nanofiltration and reverse osmosis), electromembrane (electrodialysis, electrochemical activation, electromembrane filtration), as well as adsorption and chromatographic (gel filtration using reaction columns and membrane adsorbers, ion exchange and affinity chromatography) methods;

-directed physicochemical (conversion of lactose based on the principles of homogeneous and heterogeneous catalysis; controlled chemical hydrolysis of raw milk proteins) and biological (hydrolysis, transgalactosylation and fermentation of lactose; proteolysis of whey proteins to obtain biogenic peptides and hydrolysates with a controlled level of conversion) transformation of secondary milk components raw materials.

It is the results of fundamental and applied research in these areas that led to the creation at the turn of the 20th and 21st centuries of a new generation of dairy products enriched with prebiotics and other classes of biologically active food supplements. In recent years, taking into account modern achievements in nano- and biotechnology, a number of directions have been outlined for improving the technology of functional concentrates based on whey. The use of baromembrane and electromembrane methods for processing secondary dairy raw materials opens up new opportunities for improving the technology of functional concentrates [2]:

• Production of bifidogenic concentrates based on whey with controlled mineral content;

• Exclusion of the use of alkaline catalysts for the reaction of lactose isomerization due to the use of reagentless methods for regulating the pH of secondary milk raw materials (electrochemical activation, anion exchange);

•Obtaining glucose-galactose concentrates, low-lactose drinks, galactooligosaccharides from whey permeate;

• Production of whey protein concentrates with a controlled level of proteolysis and enrichment of prebiotic carbohydrate concentrates with whey protein hydrolysates.

• Biomembrane technologies for the immobilization of lactase preparations using semipermeable membranes (devices with hollow fibers) and semipermeable surface layers (gel filtration).

MATERIALS AND METHODS

The results of research carried out since 2014 within the framework of the scientific school "Living Systems" and Professor I.A. Evdokimov made it possible to formulate a scientific concept for obtaining prebiotic concentrates based on whey with controlled carbohydrate, amino acid and mineral composition, based on the following theoretical provisions [3].

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1. The use of centrifugal, baro- and electromembrane processes for the fractionation of dairy raw materials in order to obtain semi-finished products with a given chemical composition and physico-chemical parameters, as well as target products of the required quality level.
2. Regulation of pH and mineral composition of milk protein-carbohydrate raw materials, specific chemical activity of its components in reactions based on chemical and enzymatic catalysis, by methods of electrochemical activation and ion exchange.
3. Directed physicochemical and enzymatic transformation of raw milk lactose into derivatives that impart physiologically functional properties to whey concentrates.
4. Controlled enrichment of concentrates containing lactose derivatives with milk proteins and their hydrolysates in order to improve their functional and technological characteristics, improve prebiotic (bifidogenic) properties and optimize in terms of biological value.
5. Modeling, optimization and scaling under production conditions of technological processes for obtaining prebiotic concentrates based on whey.

RESULTS AND DISCUSSION

As part of solving a set of problems related to the establishment of the main regularities and optimal parameters of the isomerization reaction and biotransformation of lactose (temperature, duration of thermostating, pH of the reaction mixture), various types of lactose-containing raw materials presented in Table 1 were considered as research objects.

Table 1 - Objects of study of the processes of isomerization and biotransformation of lactose [4]

Types of lactose-containing raw materials	Processes used for pre-treatment of lactose-containing raw materials
Raw milk sugar solutions	Purification of non-sugars
Milk whey (cheese and cottage cheese)	Isolation of fat and casein dust, pre-concentration by vacuum evaporation or reverse osmosis
Demineralized whey (cheese and cottage cheese)	Preconcentration, demineralization by electrodialysis
Cheese whey and skimmed milk permeates	Preconcentration, ultrafiltration

The regularities of the process of lactose isomerization in curd whey were studied in comparison with the control - solutions of raw milk sugar (Figure 1).

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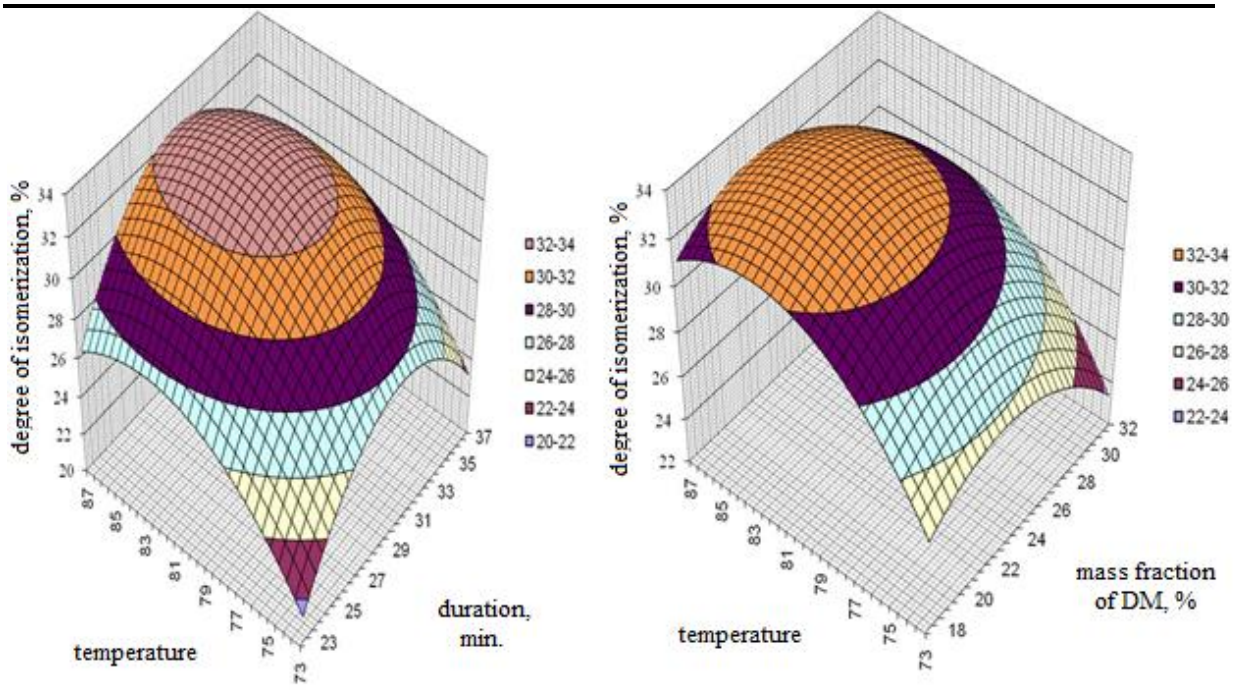

Figure 1 - Response surfaces of the output parameter of the degree of isomerization of lactose into lactulose in a solution of raw milk sugar of 5% concentration (a) and in curd whey (b)

Calcium hydroxide solution was used to regulate the pH of curd whey. An analysis of the patterns of lactulose synthesis in curd whey shows that temperature variation has a significant effect on the yield of the target product and the rate of the isomerization reaction. The maximum value of the degree of isomerization is achieved at a reaction temperature of 90 C. At the same time, in the temperature range (80–90) C, the yield of the target product increases slightly with a sharp decrease in the pH values of the medium.

The decrease in the degree of isomerization of lactose into lactulose in whey compared with the control is due to the lower quality of raw materials for lactose, which confirmed the feasibility of studying the effect of the mass fraction of solids, mineral and amino acid composition of raw materials on the efficiency of lactulose synthesis.

Regularities were studied and optimization of the parameters of the process of lactose isomerization in concentrated curd whey with a mass fraction of solids of 20, 30 and 40% at a pH of 10.8 ± 0.1 units was carried out. Mathematical processing of experimental data and graphical models of the process (Figure 2) made it possible to establish the values of technological factors, under which the degree of lactose isomerization of 30–33% is achieved (mass fraction of lactulose 5.9 ± 0.6%) [6].

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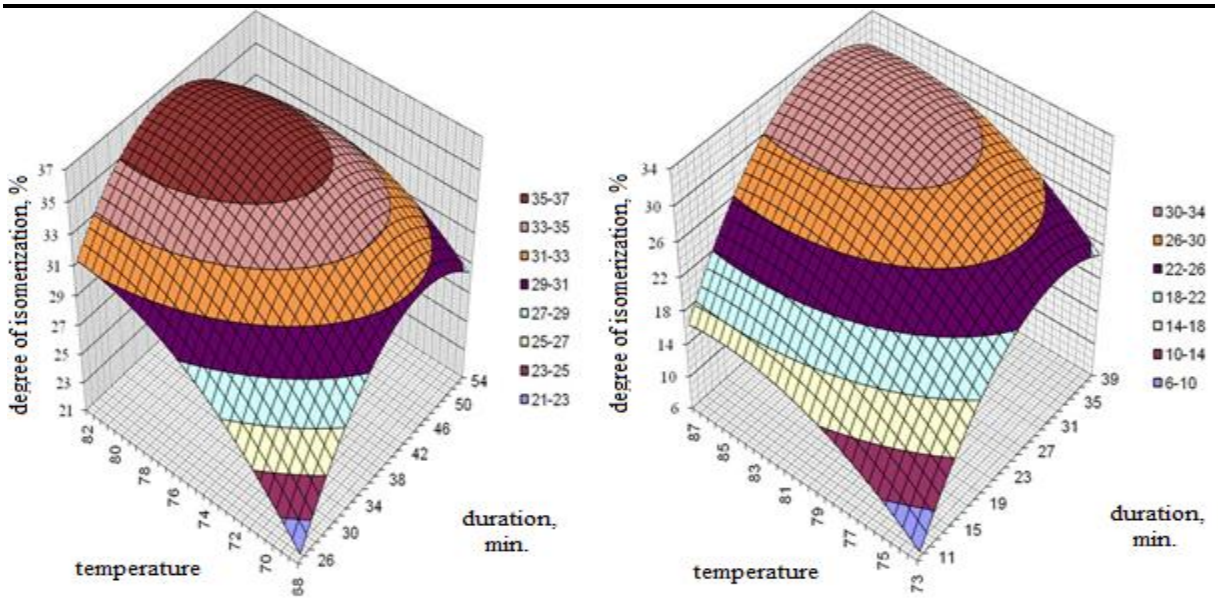

Figure 2 - Response surfaces of the output parameter of the degree of isomerization of lactose into lactulose concentrated whey

An analysis of the experimental data made it possible to conclude that it is expedient to carry out the isomerization of lactose into lactulose in concentrated whey, subject to the established values of technological factors.

A promising direction in the modernization of the technology of products with hydrolyzed lactose is the introduction of reagent-free methods for regulating the pH of reaction systems. In particular, it is of interest to improve the methods of heterogeneous chemical and enzymatic hydrolysis of lactose by optimizing the parameters of the cation-exchange treatment of lactose-containing raw materials.

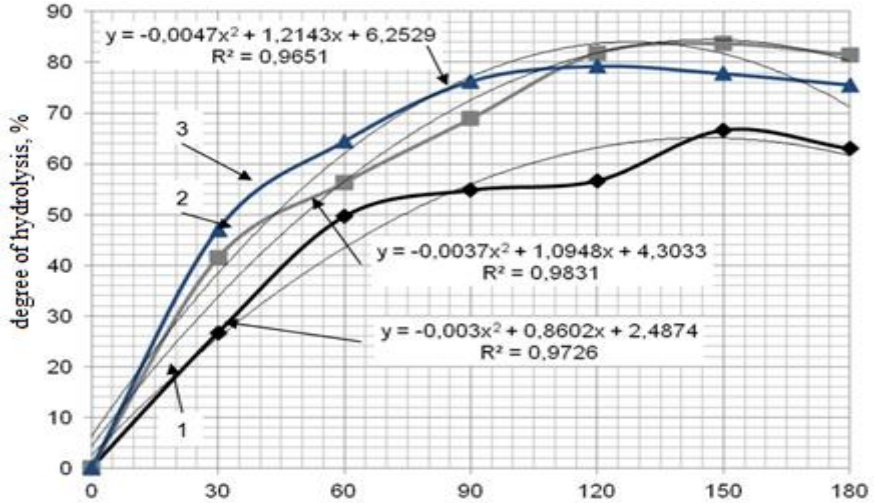

Figure 3 - Dynamics of changes in the degree of lactose hydrolysis during the fermentation of cheese whey permeate subjected to cation exchange treatment with the drug "Laktokanescin G20x" at temperatures: 1 - 45 C, 2 - 50 C, 3 - 55 C

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The regularities of the enzymatic hydrolysis of lactose in cheese whey permeate treated on the KU-2-8 chs cation exchanger to pH 4.0 at temperatures of 45,
50 and 55 C (Figure 3). For hydrolysis, the preparation of fungal β-galactosidase "Lactocanescin G20x", selected according to the results of preliminary experiments, was used. The dose of the enzyme was 0.2% by weight of the raw material. The maximum degree of lactose hydrolysis was 84% at a temperature of 50 C and a fermentation time of 120-150 minutes.

Generalization of experimental data confirmed the feasibility of regulating the pH of whey permeate by cation exchange treatment to values corresponding to the optimum action of fungal lactase preparations. An increase in the degree of hydrolysis during pretreatment of the permeate on the cation exchanger KU-2-8 hs relative to the control (fermentation without preliminary regulation of the pH of the medium) may be associated with partial demineralization of the raw material and, as a result, a decrease in the effect of β-galactosidase inhibition.

An analysis of the research results made it possible to form a system of technologies for prebiotic concentrates based on whey with controlled carbohydrate, amino acid and mineral composition. The range of prebiotic concentrates in the future can be represented by fourteen product lines with a regulated carbohydrate, mineral and amino acid composition, including more than 60 types of target products. Systematization of alternative options for obtaining and functional purpose of concentrates allows us to distinguish three assortment groups:

– Bifidogenic concentrates with lactulose based on natural and demineralized whey, with possible enrichment with raw milk proteins;

–Glucose-galactose concentrates based on whey and its permeate,

– Complex prebiotics containing lactose hydrolysis products, lactulose and galactooligosaccharides.

CONCLUSION

1. An analysis of current trends in the development of the dairy industry in Russia and abroad confirms the relevance of developing and improving technologies for obtaining prebiotic concentrates based on deep fractionation of secondary milk raw materials by baro and electromembrane methods, as well as targeted physicochemical and biological transformation of lactose.

2. Based on the results of studies of the patterns of lactose isomerization in various types of milk protein-carbohydrate raw materials (natural, concentrated and demineralized whey; permeates obtained by ultrafiltration), the optimal parameters for the synthesis of lactulose prebiotic were established.

3. Kinetic patterns of lactose biotransformation (hydrolysis and transgalactosylation) in whey and skimmed milk permeates under the action of β-galactosidase preparations were studied, reaction parameters were optimized.

4. The results of the research formed the basis for the development of technology for prebiotic (bifidogenic) concentrates enriched with lactulose; glucose-galactose

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concentrates; complex prebiotics containing lactose hydrolysis products, lactulose and galactooligosaccharides.

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