UDC: [637.344.8:637.057:663.051]

RESEARCH ON WHEY AROMA PRECURSORS IN THE TECHNOLOGY OF FLAVOURED CULINARY FOAM

T. Synenko[1], Post-graduate student
A. Bezusov[2], Doctor of Sciences in Engineering, Professor
H. Dubova[1], Candidate of Technical Science, Associate Professor
[1] Department of Technology of milk and meat
Sumy national agrarian university
Herasym Kondratiev Str., 160, Sumy, Ukraine, 40021
[2] Department of bioengineering and water
Odessa National Academy of Food Technologies
Kanatnaya Str., 112, Odessa, Ukraine, 65039

DOI: https://doi.org/10.15673/fst.v14i1.1648

Article history

Received 02.06.2019
Reviewed 14.08.2019
Revised 15.10.2019
Approved 04.02.2020

Correspondence:

H. Dubova
E-mail: hdubova16@gmail.com

Cite as Vancuver style citation

Synenko T, Bezusov A, Dubova H. Research on whey aroma precursors in the technology of flavoured culinary foam. Food science and technology. 2020;14(1):70-80. DOI:https://doi.org/10.15673/fst.v14i1.1648

Цитування згідно ДСТУ 8302:2015

Synenko T., Bezusov A., Dubova H. Research on whey aroma precursors in the technology of flavoured culinary foam // Food science and technology. 2020. Vol. 14,Issue 1. P. 70-80 DOI:https://doi.org/10.15673/fst.v14i1.1648

Abstract. The purpose of this work is to study the ability of whey aroma precursors to form new volatile components under model conditions. The formation of new aromas has been considered as a two-stage process: enzymatic cleavage of the precursors and the subsequent Maillard reaction. The properties of whey components have been studied for their ability to form or modify aromatic descriptors at different stages of enzymatic cleavage of aroma precursors. It has been proved that targeted enzymatic reactions with whey components result in formation of sweet, meat, cheese aromas at different stages of whey protein breakdown after interaction with carbohydrates. It has been studied how the depth of proteolysis influences the subsequent formation of smells from precursors. It has been established that lactose cleavage products in whey do not play a significant role in aroma formation. Unlike proteolytic enzymes, lactase (β-galactosidase) does not change the aromatic characteristics of the modified whey. An increase in the concentration of lactulose, a potential aroma precursor in sugar-amine reactions of whey, only adds a sweetish note and does not change a smell significantly. Aroma formation in modified whey has been consistently investigated, and a technological scheme of flavoured culinary foam based on it has been tested. It has been shown that the addition of 5–10% sodium chloride to the bottom residue after rectification of whey from fermented milk makes the aroma of the final product far more stable. It has been found that the specific odour of whey, limiting its use as food, can be modified by using new approaches to reactions with aroma precursors. We have considered the fixation of the obtained aromas "Mushroom Soup," "Bouillon," "Cheese" on an oily carrier for subsequent concentration and use in various products.

Keywords: whey, aromatic descriptor, enzymes, precursor, reaction conditions, culinary foam.

Introduction. Formulation of the problem

The low organoleptic characteristics of whey (its specific taste and albumin flavour) make it difficult to use it as a basis for food products [1-7]. Whey is used as a source of flavouring agents obtained industrially for meat enterprises [2,3], and in the course of their production, it loses all its consumer properties, but the aromatic ones [8]. Our previous studies showed that it was possible to change the whey flavour by enzymatic proteolysis and at the same time preserve it as the basis of a food product to be prepared [9]. This approach proves the most practical in the preparation of foam, because proteolysis products form foam better than native proteins do. Aromatic culinary foam is a relatively new food product that has but few analogues in the consumer market. The start-up *Skinny Eats*, a low-calorie salad dressing based on hydrolysed proteins and oleoresins from 8 directions, was developed several years ago [10]. Oleoresins lack a lot of aroma descriptors, for example, "cream-and-bouillon," or "soup-and-mushroom."

Analysis of recent research and publications

Whey components, when acted upon under certain conditions, may have the properties of aroma precursors. In the production of hard cheese and curd cheese, most of the aromatic substances that determine the specific taste and smell of whey are formed due to enzymatic transformations of casein and fat in milk. As a result of these transformations, peptides, free amino acids, aldehydes, ketones, and volatile fatty acids are formed [2,11]. Partially, the components of milk pass on into whey and can serve as precursors for aromatic substances during subsequent enzymatic reactions. For example, there is

a patented method for the production of a cheese flavouring agent based on a mixture of whey, milk, and an enzyme complex [12]. Whey components are used as the base for aromatic and flavouring substances. For example, whey lactose is used as the base to manufacture the aroma and flavour substance *Aroma*, a component of a sausage recipe [13]. Lactose hydrolysates are used as glucose-galactose syrups. However, aroma changes in the enzymatic reactions used are not described [3,13-16].

Substances that are involved in the formation of taste and aroma of whey are of different volatility, so it is impossible to improve significantly its organoleptic characteristics by deaeration, deodorisation, or vacuum concentration [2]. The reactions of enzymes that form new aromatic descriptors with whey components or remove the unpleasant odour of whey have not been adequately investigated. Publications on enzymatic changes in whey pay much attention to hydrolysis of whey proteins, since it is not proteins themselves, but their decomposition products that are more valuable [17,18]. The substrate properties of the main whey proteins hydrolysed by various proteases have been described [19,20-24]. The result achieved by the authors (cleavage of 60–80% β-lactoglobulin and 30% α-lactoglobulin, and preservation of whey albumin) is of interest, as it relates to changing the aromatic profile of whey protein concentrate. M. Kurbanova notes that alkaline hydrolysis of milk proteins produces an unpleasant taste, and that by selecting enzymes, it is possible to obtain a hydrolysate without a bitter taste [25]. For example, the author notes that when casein is hydrolysed in the presence of the enzyme Alcalase, a bitter taste appears with the minimum degree of hydrolysis. However, no attention is paid to how the aroma that accompanies the taste characteristics is changed during enzymatic hydrolysis.

So, **the purpose** of this research is to study the ability of whey aroma precursors to form new volatile components under thermal and enzymatic action.

To achieve this purpose, the following **objectives** were to be solved:

1. To study the process of changes of whey aromas under model conditions.
2. To obtain modified whey with a required aroma.
3. To develop a technological scheme of obtaining flavoured culinary foam based on the modified whey.

Research materials and methods

Raw materials. The experimental studies were conducted with the use of fresh whey (cheese curd whey) obtained as a by-product of fermented milk curd manufacture. The whey was yellowish in colour, with the lactose content 4.0 wt.%, with the mass fraction of milk fat 0.5%, that of protein 0.6%, active acidity 4.5, titratable acidity 70°T, with a pronounced aroma of raw whey and a slight note of fermented milk.

The whey components were split by the enzymes of different origin (Table 1): pepsin (12,000 IU), chymotrypsin (1500 IU), lactase (3000 IU), lipase (20,000 IU).

Preparation of the samples. The studies were performed according to the scheme in Fig. 1.

Table 1 – Comparative characteristic of enzymes [26, 27]

Type of enzyme	General name/source	Optimum range		Substrate	Product
		pH	temperatures, °C		
Aspartic (acid) protease. Animal origin	Pepsin (EC number 3.4.23.1)/pig's stomach	1.5–2.5	40–50	Catalyses hydrolysis of peptide bonds formed by amine groups of aromatic amino acids (tyrosine and phenylalanine)	Peptides (peptones), free amino acids
Esterase. Microbial origin	Lipase (EC number 3.1.1.3)/*Candida rugosa*	7.8–8.0	30–40	Catalyses hydrolysis of insoluble triglycerides	Glycerine and free long-chain fatty acids
Serine protease. (animal)	Chymotrypsin (EC number 3.4.21.1)/pig's stomach	7.8–8.2	40–50	Catalyses hydrolysis of peptide bonds formed by amine groups of aromatic amino acids (tryptophan, tyrosine, and phenylalanine)	Amino acids
Carbohydrase (microbial)	Lactase (EC number 3.2.1.23)/*Escherichia coli*	6.7–7.0	28–32	Catalyses hydrolysis of glycosides bonds	Glucose and galactose
Cysteine protease (vegetable)	Papain (EC number 3.4.22.2)/papaya juice	6.0–7.0	40–60	Catalyses hydrolysis of almost any peptide bonds	Amino acids

To obtain the test samples, 400 cm^3 of whey was transferred to a 500 cm^3 volumetric flask, and heated to 40–50°C. Then, a solution of the enzyme (Table 1) or enzyme mixtures (pepsin and chymotrypsin), in the amount 40 cm^3, was added. To prepare the enzyme solution, 5 g of the enzyme preparation was added to 40 cm^3 of distilled water at 38–42°C. Depending on the enzyme used, the pH of the medium was changed by adding a solution of hydrochloric acid (2N HCl) or of sodium hydroxide (1H NaON) in the whey samples. Hydrochloric acid was added till the pH of the whey was 2.0, the sodium hydroxide solution was added until the pH of the whey was 8.0. The samples were stirred thoroughly for 5 min on a magnetic stirrer at the optimum temperature specified in Table 1 for each enzyme.

Fig. 1. Scheme of obtaining modified whey

It is difficult to use simultaneously a combination of enzymes because they have the maximum effect at different optimum pH. That is why, 40 cm^3 of a solution of one or several enzymes was added to the whey samples to be enzymolysed, while changing sequentially the pH of the reaction mixture (20 cm^3 of pepsin solution and 20 cm^3 of chymotrypsin solution).

The mixture of whey and enzyme solution was rested for 60 min, with the temperature maintained at 40–50°C for all samples (in the sample with lactase, the temperature was 28–32°C), constantly stirring it on a magnetic stirrer with the rotation frequency 8 rpm. Upon completion of enzymatic hydrolysis, a typical procedure of the descriptive research method was used to evaluate the aroma change processes.

The action of an aroma of protein nature on the precursors was carried out in one stage (by fermentation only) or in two stages (heat pre-treatment at 90–95°C for 5 min followed by enzymolysis using proteases (Table 1), according to the above procedure). To study the protein precursors, the whey was enzymolysed with proteolytic enzymes without changing the pH of the reaction mixture.

Isolating the volatile fractions and carrying out the Maillard reaction. To determine how the aromatic descriptors of the whey changed during the high-temperature treatment, the prepared samples were rectified in a laboratory unit at 105±1°C. The rectification unit allows combining high-temperature treatment and stripping of highly volatile components.

The fractionating process lasted 45 min, distillate fractions were collected every 15 min, the aromas of each fraction and the bottom residue were described. The conditions of rectification allowed obtaining the bottom residue with products of the Maillard reaction that took place in the samples and involved peptides, amino acids, lactose, and lactulose. Upon completion of rectification, a typical procedure of the descriptive research method was used to evaluate the aroma change processes. The effect of volatile components and Maillard reaction products on the general aroma of the bottom residue and distillate fractions was determined.

The influence of precursors of the aroma of carbohydrate nature was investigated in samples with an increased concentration of lactose and lactulose (15% by weight of the sample was added).

Aroma fixation. After the rectification, to fix the aroma, table salt (sodium chloride) was added to the bottom residue samples obtained (5% and 10% of their total mass). The prepared samples of the bottom residue and sodium chloride were subjected to high-temperature treatment by convective heating to 105±1°C for 30 min. Upon completion of the process, modified whey was obtained.

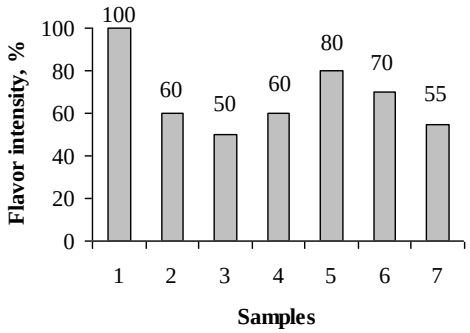
Deodorised sunflower oil, too, was used as a fixative carrier of the aroma. It was added to the samples after enzymolysis (about 10–15 cm^3, depending on the container used), until a sorptive film was formed on the surface of the mixture. It was then subjected to high-temperature treatment by convective heating to 105±1°C for 30 min. The oil film was removed through a separatory funnel on completion of the process.

Obtaining foam on soy milk. Soy milk (SM) was prepared as follows. Soybeans were soaked in cold water (with the water ratio 1:4) for 12 hours, then washed, and ground in a blender. To the ground beans, cold water was added in the ratio 1:2, then they were stirred and rested for 2–3 hours. The mixture was strained, then the filtrate called *Soy milk* (SM) was used. Modified whey was added to the filtrate. The whey to SM ratio was 1:2. The mixture was then sparged with carbon dioxide for 5 min until stable foam was obtained.

Studying the aroma. The aroma was assessed by an expert group of 11 people (women, 25–40 years old) using the descriptive, comparative, and point rating methods. A sample of whey not treated with enzymes or heat was the control. The peculiar feature of the aroma of the samples obtained is the presence of 4–6 basic descriptors and 3 tint (whey, sour, bitter). The profile charts contain descriptors and shades that have been confirmed by at least 9 experts.

Results of the research and their discussion

Native untreated whey has a specific odour, which is described as that of albumin or of secondary processed raw material. Numerous attempts to change the raw whey odour consist in adding other raw materials supposed either to obscure it or to form a new smell [2,3,28,29]. Enzymatic hydrolysis of whey components allows changing significantly the raw whey odour by destroying its carriers – proteins and lipids. The aromatic descriptors of whey were modified by enzymolysis using enzymatic solutions (Table 1). After the enzymatic hydrolysis, a comparative analysis of the samples was carried out (Fig. 2). The smell of the control sample of raw whey was taken as 100%, the presence of another smell, with the whey odour distinguishable, as 80–60%, a slight tint of whey against a certain aroma as 20%, no raw whey smell corresponded to 10%.



1 – control; 2 – pepsin; 3 – pepsin+chymotrypsin; 4 – papain; 5 – lipase; 6 – lactase; 7 – lactase+lactulose

Fig. 2. Degree of destruction of the raw whey smell by enzymolysis

The greatest changes in the aroma (Fig. 2), according to the tasters, took place when proteolytic enzymes were used. It can be stated that enzymatic breakdown of milk sugar and lipids, with the use of appropriate enzymes, effects but insignificantly on the change in the whey smell. The destruction of it consisted in the absence of the descriptor "raw, albumin, whey smell," and was equal to 40% or more for most samples. The degree of whey odour destruction can be increased, but the purpose of the work was to study aroma changes and to create new descriptors.

According to preliminary studies, the destruction of raw whey smell may depend on the depth of enzymolysis. For example, when the biuret test was negative, the crude albumin smell in the whey was almost imperceptible [9]. Under the conditions we used, the depth of proteolysis was 50–60%, which agrees with the results of similar studies [20]. This depth of proteolysis is sufficient to form new aroma descriptors from the enzymatic reaction products, which is the main objective of this study. The smallest changes in the whey odour were caused by lipase. Free long-chain fatty acids formed after enzymolysis by lipase do not smell. However, they can dissolve and accumulate volatile aroma components, thus, probably, being responsible for the albumin odour and a slight

change in the general smell of the samples. To sum up the results obtained, we can conclude that enzymatic hydrolysis modifies the smell of whey, but does not make it attractive and recognisable. The whey odour is destroyed due to the formation of peptides and free amino acids, cleavage of covalent bonds, release of individual functional groups. All samples had weak smells that were later modified by high-temperature treatment.

Aroma precursors are amino acids and their amides (series, aspartic and glutamic acids, glutamine, glycine, etc.), which accumulate in the course of autolysis during the breakdown of proteins and natural peptides, such as glutathione, carnosine, anserine [30]. Even small amounts (about 0.03 %) of glutamic acid and its sodium salt give the product a meat aroma [31]. The formation of aromatic descriptors begins at the stage of enzymatic cleavage of aroma precursors and continues during heat treatment. Aroma transformations at this stage depend on the accumulation of products of the Maillard reaction that takes place between amino acids and carbohydrates in enzymatically modified whey. After enzymatic hydrolysis, as a result of rectification of the samples, new recognisable aroma descriptors are formed (Table 2).

Table 2 – Characteristics of modified aromatic descriptors of the samples after enzymolysis and rectification

Samples	Aroma description			
	bottom residue (non-volatile aromatic components)	condensate (volatile aromatic components)		
		Fraction 1	Fraction 2	Fraction 3
Control sample	Sweet sour, with a "cooked" tone	Bitter, with a tint of whey	Bitter, no extra tint	Harsh and bitter
Pepsin	Mild, sweet, with cooked notes like those of meat broth	Slightly sour, with a hint of cheese	Slightly sour, with a hint of cheese	Harsh, slightly sour, with a hint of cheese
Pepsin + chymotrypsin	Similar to meat broth, slightly of cream and cheese	Sour with a tint of whey	Weak acidic tint	Harsh, bitter, with burnt and slightly sour notes
Papain	Similar to meat broth, with sweet fruit notes	Sour with a tint of whey	Sour, with whey and bitter tint	Harsh, bitter, with a slightly sour notes
Lipase	Typical of lipolysis, rancid, with a slightly sour tone	Bitter	Bitter, with burnt notes	Harsh, bitter, with burnt and astringent notes
Lactase	Sour, with a hint of cheese	Sweet	Sweet, with a burnt material tone	Sweetish, with a burnt material tone
Lactase + lactulose	Sweet, with sour and cheese notes	Sweet	Sweet, with a burnt material tone	Sweetish, with a burnt material tone

As shown in Table 2, after enzymolysis, various aromatic descriptors are formed due to changes in the amino acid composition in each sample. For example, methionine yields aldehyde methional, which has a meat smell, and threonine gives α-ketobutyric acid, which has a strong smell of broth [31]. These aroma changes only refer to the bottom residue and to non-volatile components that accumulate there. It is only volatile substances that pass into the condensate – the sulphurous and ammonia ones formed as a result of protein breakdown and present in whey. A possible source of sulphide formation is sulphur-containing amino acids, in particular cystine, cysteine, methionine, and peptide glutathione. Enzymatic and subsequent thermal destruction of lipids in the whey resulted in the appearance of bitter and burnt tints, both in the condensate and in the bottom residue. This is explained by the fact that during the high-temperature treatment after the enzymolysis, the lipid fraction undergoes negative changes related rather to the thermal destruction of glycerine formed after lipolysis of the whey samples. Increasing the carbohydrate content of whey by adding lactulose does not have a significant effect on aroma changes, whether at the stage of enzymolysis or during the further formation of the bottom residue. The tasters only noted the presence of some sweetish tints. The change in the whey odour in the condensate and the bottom residue shows that the greatest changes result from the formation and accumulation of non-volatile and semi-volatile components that do not undergo distillation and rectification.

Studies of the aroma of the bottom residue after enzymolysis of whey by a combination of pepsin and chymotrypsin have shown that aromatic descriptors manifest themselves as long as the residue is hot (60–80°C). When the bottom residue is cooled to 25°C, the aroma is barely detectable. Obviously, cooling is accompanied by mass transfer between the highly volatile aroma components and the bottom residue. To prevent this mass transfer, it is necessary to use aroma

fixatives for the further testing of the processes under study.

Amino acids and carbohydrates of whey are not carriers, but potential smell precursors. As such, whey proteins can give better results when the pH optimum is not provided for proteolytic enzymes. This is due to the fact that not all amino acids are equally involved in aroma formation, and for the subsequent sugar-amine reactions, too, the depth of enzymolysis can be sufficient at whey's native pH.

To determine the role of whey amino acids in aroma formation, descriptors of the whey samples (with the native pH 4.5) were examined after the samples had been enzymolysed with solutions of pepsin, papain, chymotrypsin, and a combination of pepsin and chymotrypsin, and then rectified. The aroma of the bottom residue is shown in Fig. 3.

According to the results of experiments and the taste panel's protocols, it can be stated that in whey, enzymolysis with the natural pH 4.5, followed by high-temperature treatment is effective as to the formation of aromas. There are two reasons for this: enough enzyme activators in whey (mineral and minor components [3,11,25,26,27]), and the conditions under which enzymes perform only one reaction, always the direct one, and never the inverse one. Besides, during heating, aldehydes are formed from amino acids in the course of their oxidative decarboxylation and deamination. These aldehydes influence the formation of new aromatic descriptors [3,11]. High-temperature treatment of the samples after enzymolysis with a one enzyme, pepsin or chymotrypsin, gives different descriptors with different intensity: cooked, sour (with chymotrypsin), or sweet, meaty (with pepsin). Thus, to obtain modified whey and prepare aromatised foam based on it, we do not recommend changing the pH of the enzyme solutions.

Low-molecular-weight products of splitting whey proteins (amino acids obtained after enzymolysis of whey) react with lactose during high temperature treatment [3,11]. At the beginning of the sugar-amine reaction, lactose interacts with free amino acid groups, and thus lactosamine is formed [3,11]. Further, such substances as lactulosamine, lactulose (lactulose-lysin), various aldehydes, etc. are formed [11,31,32]. In the course of the reaction, intermediate products are formed, too. They are responcible for the appearance of a specific odour.

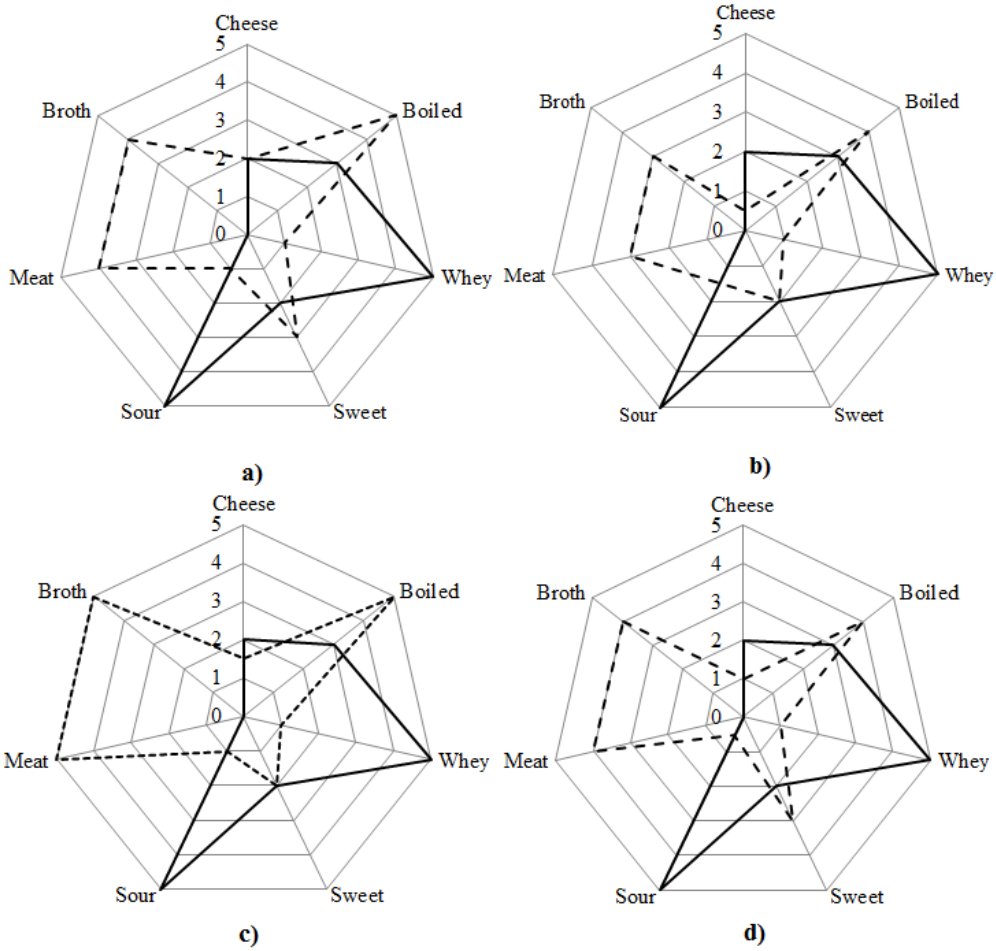


Fig. 3. Change in the aromatic descriptors of the modified aroma of whey depending on the enzyme used, without changing the pH: a) pepsin; b) chymotrypsin; c) pepsin/chymotrypsin; d) papain

Substances resulting from the reaction when amino acids interact with disaccharides have characteristic aromatic descriptors that depend on the amino acid involved in the reaction. Substances produced from phenylalanine and glycine have a caramel flavour; those from leucine, arginine, and histidine have the bread crust aroma; from alanine a nutty flavour; from proline a baked smell; from glutamine and lysine a buttery flavour; from methionine a bouillon smell or that of beans; from cysteine and glycine smoky and burnt smells; from arginine the popcorn flavour; from α-Aminobutyric acid a walnut flavour [32,33]. Short-chain free fatty acids (acetic, propionic, butyric, caproic), too, are important in the formation of the aroma and taste. They not only directly participate in the formation of the fragrance, but increase the sensitivity threshold of other substances.

Conformational changes and processes of interaction of protein macromolecules, as well as the nature of the structures formed in such an interaction, effect greatly on the formation and stability of flavours derived from them. Every whey protein has its own "denaturation threshold." Blood albumin and immunoglobulins are less heat-resistant whey proteins. As for β-lactoglobulin and α-lactalbumin, these proteins are quite resistant to heating [19,28,31]. Unfolding and stabilisation of a protein globule can occur in the presence of salts, including sodium chloride. That is why, most technologies of production of flavouring agents based on protein hydrolysate involve the addition of table salt. The formation of a persistent aroma was carried out in the bottom residue by adding sodium chloride (5% and 10% by weight of the sample). Next, the modified whey was subjected again to heat treatment at 105±1°C for 30 min, cooled, and the aroma was examined with an interval of 60 min (Fig. 4). To characterise its stability, a scale of values from 0 to 100 points was used, where up to 30 points meant a noticeable aroma, 30–70 points were for a pronounced aroma with quite distinct tints, 70–100 points for an easily recognised, well-pronounced aroma, with intense tints.

Adding 5% or 10% of sodium chloride allows preserving the aroma of the modified whey after cooling for 3 hours. After 3 hours, the sensory threshold for the samples is somewhat lowered due to a decrease in the concentration of volatile components. Thus, the addition of sodium chloride to the bottom residue followed by heat treatment forms a persistent aroma, intense for 3 hours.

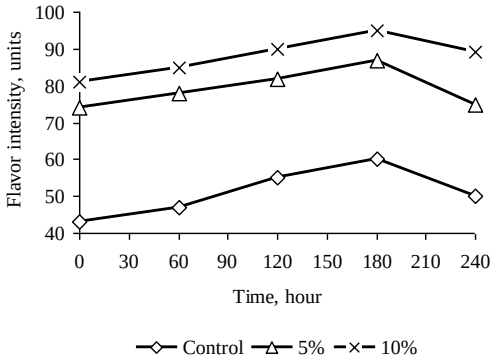


Fig. 4. Changes in the intensity of the modified aroma

Vegetable oils are known for their capacity to absorb and hold volatile substances. Refined deodorised sunflower oil was studied as a fixative carrier of the aroma. Volatile substances that are Maillard reaction products change the product's general aromas and are partly separated with the vapour during boiling. Adding vegetable oil as a sorptive film on the surface of the samples helps to retain some volatile components in the mixture. The modified flavour thus obtained and such descriptors as "broth-like," "meat-like," "cheese," "cooked" are transferred onto an oily carrier and become a concentrated product in its own right.

To obtain the finished product, flavoured foam, we experimented with combinations of modified whey and SM. The search of a foaming component suitable by its aromatic and taste qualities showed the advantages of plant milk. SM has sufficient foaming properties, so we used it as an ingredient of flavoured protein foam (Table 3). It has been noted that SM can enhance the tint of meat and cheese in the aroma.

Table 3 – Composition and characteristics of the aroma of the flavoured foam

Component	Quantity	Parameters of treatment	Aroma
Whey, cm^3	200	Enzymatic hydrolysis, rectification, heat treatment of the bottom residue in the presence of sodium chloride and soy milk	Broth, soup, cheese, mushroom (tint), sour cream (tint)
Soy milk, cm^3	200	Mixing with whey and sparging	Meat, cheese (tint)
Enzymes (papain), mg	100	Preparation of an aqueous solution, stirring, and keeping in a thermostat for 5 min, adding to whey	Absent
Table salt, g	20	Adding to whey after enzymolysis	Absent
Foam base *Nika-foam*, cm^3	500	Sparging with carbon dioxide to obtain a stable foam	Broth, meat, soup, sour cream

There are three main stages in the flavoured foam production: I – enzymolysis; II – modification of the raw materials (changing the aroma, Maillard reaction); III – obtaining foam. A process chart of production of flavoured foam is shown in Fig. 5.

The peculiar feature of the resulting foam is that the aromatic components in it are in a more accessible form and on a larger surface area, which greatly enhances the obtained descriptors of the modified whey aroma.

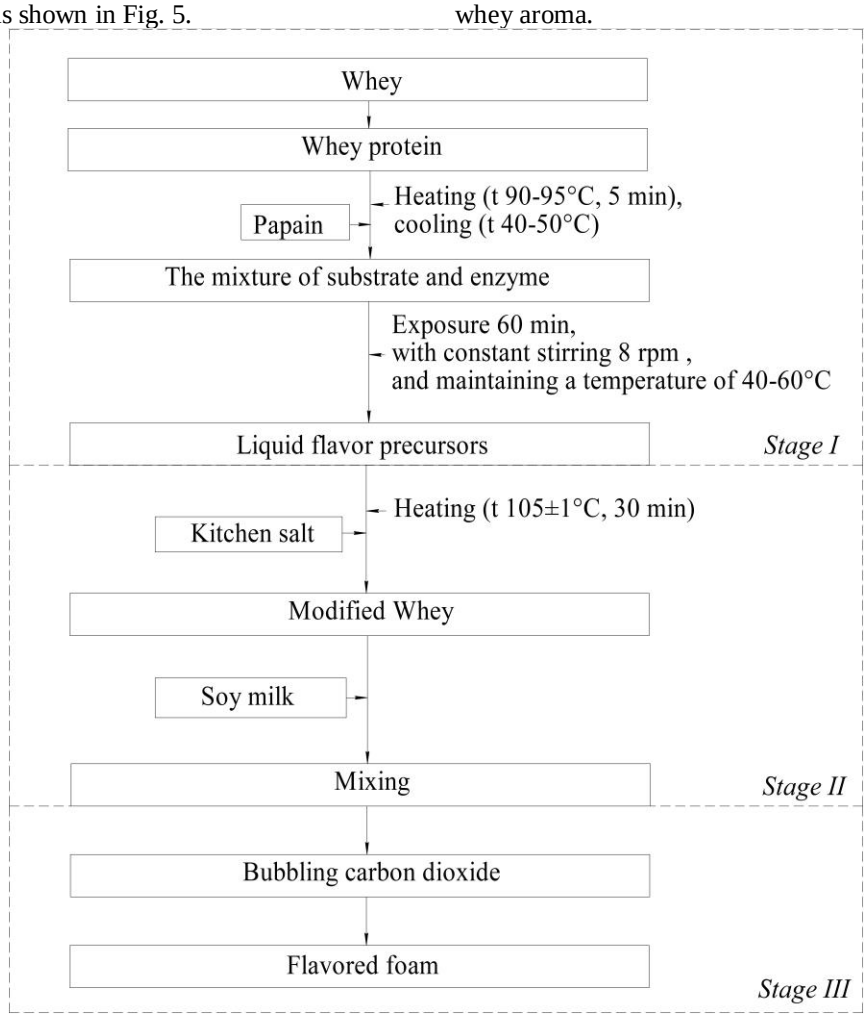


Fig. 5. Process chart of obtaining flavoured foam

Approbation of results

The preliminary marketing studies conducted at Sumy National Agrarian University have shown that this foam can be in high demand with people who comply with certain food limitations, for example, vegetarians and raw foodists. The technology of flavoured protein foam has been patented, and its name *Nika-foam* has been copyrighted. Further research is now in progress to improve the consumer characteristics of the foam.

Conclusion

The study of changes in the aromas of whey under model conditions has shown that proteolysis of whey proteins removes the specific whey odour. The depth of proteolysis when using whey with native pH is sufficient both to eliminate the raw odour and to form new descriptors in the following sugar-amine reaction. The formation of new aromas in the two-stage process (enzymatic cleavage and the Maillard reaction) consists in transforming the precursors into the aromas of broth, meat, soup, cheese. Obtaining modified whey with required aromas depends on the transformation of protein precursors. Whey lipids and carbohydrates do not significantly effect on aroma formation. Complex enzymatic reactions with whey components lead to the formation of sweet, meat, cheese aromas at different stages of cleavage of whey proteins. A technological scheme of obtaining flavoured foam has been developed based on the modified whey. The specific aroma of whey, limiting its use as food, is modifiable due to new approaches to reactions with aroma precursors.

Referenses:

1. Zhidkov VYe. Nauchno-tekhnicheskiye osnovy biotekhnologii al'ternativnykh variantov napitkov iz molochnoy syvorotki. Rostov n/D: SKNTS VSH; 2000.
2. Mel'nikova YeI. Issledovaniye biotekhnologicheskogo potentsiala tvorozhnoy syvorotki: modifikatsiya khimicheskogo sostava, prognozirovaniye kachestva i novyye tekhnologicheskiye resheniya [dissertation]. Voronezh: Voronezhsaya gosudarstvennaya tekhnologicheskaya akademiya; 2007.
3. Khramtsov AG. Fenomen molochnoy syvorotki. SPb.: Professiya; 2011.
4. Korenman YAI, Mel'nikova YeI, Chubirko MI, Niftaliyev SI, Svetolunova SYe. Gazokhromatograficheskiy i mikrogravimetricheskiy analiz aromatobrazuyushchikh komponentov molochnoy syvorotki. Izvestiya vuzov. Khimiya i khimicheskaya tekhnologiya. 2004;47(10):140-142.
5. Wolf IV, Bergamini CV, Perotti MC, Hynes ER. Sensory and flavor characteristics of milk, production, composition and health. In: Park YW, Haenlein G, editors. Milk and dairy products in human nutrition. Oxford: John Wiley and Sons; 2013. p. 310–29. https://doi.org/10.1002/9781118534168.ch15.
6. Mortenson MA, Vickers ZM, Reineccius GA. Flavour of whey protein concentrates and isolates. International dairy journal. 2008;18(6):649-657. https://doi.org/10.1016/j.idairyj.2007.12.003.
7. Whetstine MC, Parker JD, Drake MA, Larick DK. Determining flavour and flavour variability in commercially produced liquid Cheddar whey. Journal of dairy science. 2003;86(2):439-448. https://doi.org/10.3168/jds.2012-5935.
8. Musiychuk O. Perspektyvy vykorystannya produktu pererobky molochnoyi syrovatky. Tovary ta rynky. 2008;1:78-83.
9. Synenko TP, Dubova HYE. Kharakterystyka aromatychnykh deskryptoriv produktiv rektyfikatsiyi molochnoyi syrovatky. Prohresyvni tekhnika ta tekhnolohiyi kharchovykh vyrobnytstv restorannoho hospodarstva i torhivli. 2019;1 (29):63-74.
10. Digital.NYC Weekly [cited 2019 May 12]. Available from: http://www.digital.nyc/startups/skinnyeats.
11. Gorbatova KK, Gun'kova PI. Khimiya i fizika moloka i molochnykh produktov. SPb.: GIORD; 2012.
12. John C. Watts Jr., John H. Nelson. Cheese flaworing process. United States patent 3072488. 1963.
13. Sinel'nikov BM., Khramtsov AG., Yevdokimov IA., Ryabtseva SA., Serov AV. Laktoza i yeye proizvodnyye. SPb.: Professiya; 2007.
14. Avdalyan GV. Tekhnologiya glyukozo-galaktoznogo siropa na osnove kislotnogo gidroliza laktozy. Moskva: Vses. nauch.-issled. i konstrukt. in-t myasnoy prom-sti; 1990 [cited May 12, 2019]. Available at: http://tekhnosfera.com/tehnologiya-glyukozo-galaktoznogo-siropa-na-osnove-kislotnogo-gidroliza-laktozy.
15. Musina ON, Lisin PA. Syvorotka i produkty iz neye: analiz patentnoy situatsii. Molochnaya promyshlennost'. 2008;4(12):79-80.
16. Sviridenko YuYa, Abramov DV, Sviridenko GM. Produkty na osnove fermentativnogo gidroliza laktozy i belkov molochnoy syvorotki. Pererabotka moloka. 2007;2(1):56-57.
17. Tsigankov VG, Golovach TN, Kurchenko VP, Bondaruk AM. Issledovaniye peptidnykh fermentativnykh gidrolizatov kontsentrata syvorotochnogo belka korov'yego moloka dlya razrabotki produktov pitaniya dlya turizma i otdykha. Trudy BGTU. 2015;1(174):272-275.
18. Sydorov YuI. Rozrobka tekhnolohiyi vyrobnytstva biolohichno aktyvnoyi sumishi aminokyslot z molochnoyi syrovatky. Visnyk Natsional′noho universytetu «L′vivs′ka politekhnika». 2008;622:88-95.
19. Berozkina KA, Agarkova YeYu, Budrik VG. Napravlennyy fermentoliz belkov molochnoy syvorotki. Pererabotka moloka. 2014;2(7):20-22.
20. Golovach TN, Gavrilenko NV, Zhabanos NK, Kurchenko VP. Zakonomernost' gidroliza syvorotochnykh belkov ekzo- i endoproteinazami. Trudy Belorusskogo gosudarstvennogo universiteta. 2008;3(1):1-15.
21. Kuhn J. Studies on interactions of milk proteins with flavour compounds [dissertation]. New Zealand: Palmerston North; 2007.
22. Kelleher SL, Chatterton D, Kelleher SL, Niehen K., Lonnerdal B. Glycomacropeptide and alpha-lactalbumin supplementation of infant formula affects growth and nutritional status in infant rhesus monkeys. American Journal of Clinical Nutrition. 2003;77(5):1261-1268. https://doi.org/1261-1268. 10.1093/ajcn/77.5.1261.
23. Papiz MZ, Sawyer L, Eliopoulos EE, North ACT, Findlay JBC, Sivaprasadarao R, et al. The structure of β-lactoglobulin and its similarity to plasma retinol-binding protein. Nature. 1986;324:383-385. https://doi.org/10.1038/324383a0.
24. Boye JI, Alli I. Thermal denaturation of mixtures of α-lactalbumin and β-lactoglobulin: a differential scanning calorimetric study. Food Research International. 2000;33:673-682. https://doi.org/10.1016/S0963-9969(00)00112-5.
25. Kurbanova MG. Fermentativnyy gidroliz molochnykh belkov s ispol'zovaniyem razlichnykh proteaz. Vestnik KrasGAU. 2010;1(40):157-160.
26. Dixon M, Webb EC. Enzymes. New York: Academic Press; 1980. DOI: https://doi.org/10.1021/ed042pA486.3.
27. Gracheva IM, Krivova AYu. Tekhnologiya fermentnykh preparatov. Moskva: El'svar; 2000.
28. Krus' GN, Shalygina AM, Volokitina ZV. Metody issledovaniya moloka i molochnykh produktov. Moskva: Kolos; 2000.
29. Novokshanova AL, Nepovinnykh NV, Abramov DV. Issledovaniye vliyaniya gidrolizata syvorotochnykh belkov na organolepticheskiye pokazateli osnov kislorodnykh kokteyley. Vestnik Mezhdunarodnoy akademii kholoda. 2016;2:4-9. https://doi.org/10.21047/1606-4313-2016-15-2-4-9.
30. Tkachenko OB, Trynkal′ OV. Khymymya aromatov vyna. Kharchova nauka i tekhnolohiya. 2015;1(30):42-50.
31. Gren' AI, Vysotskaya LYe, Mikhaylova TV. Khimiya vkusa i zapakha myasnykh produktov. Kiyev: Naukova dumka; 1985.
32. Davidek T, Blan I, Khofmann T, Shiberl P. Vkusoaromaticheskaya aktivnaya kompozitsiya. Patent RU 2577409. 2010.
33. Khudyakov KYu, Azolkina LN. Voprosy glubokoy pererabotki moloka pri proizvodstve myagkogo syra. In: Materialy II mezhregional'noy nauchno-prakticheskoy konferentsii (s mezhdunarodnym uchastiyem). Alt. gos. tekhn. un-t im. Polzunova II; 2018. Barnaul: Izd-vo AltGTU; 2018: 264-267.

ДОСЛІДЖЕННЯ ПОПЕРЕДНИКІВ АРОМАТУ МОЛОЧНОЇ СИРОВАТКИ В ТЕХНОЛОГІЇ АРОМАТИЗОВАНОЇ ПІНИ

Т.П. Синенко[1], аспірант, E-*mail*: tanyushka.sinenko@gmail.com
А.Т. Безусов[2], доктор технічних наук, професор, E-*mail*: anatoliy.bezusov@gmail.com
Г.Є. Дубова[1], кандидат технічних наук, доцент, E-*mail*: hdubova16@gmail.com
[1] Кафедра технології молока і м'яса
Сумський національний аграрний університет, вул. Герасима Кондратьєва, 160, м. Суми, Україна, 40021
[2] Кафедра біоінженерії і води
Одеська національна академія харчових технологій, вул. Канатна, 112, м. Одеса, Україна, 65039

Анотація. Метою представленої роботи є дослідження здатності попередників аромату молочної сироватки до утворення нових летких компонентів у модельних умовах. Формування нових ароматів розглянуто в аспекті двоступеневого процесу – ферментативного розщеплення попередників і подальшої реакції Майяра. Розглянуто властивості компонентів молочної сироватки за здатністю утворювати або змінювати ароматичні дескриптори на етапах ферментативного розщеплення попередників аромату. Доведено, що цілеспрямовані ферментативні реакції з компонентами молочної сироватки призводять до утворення солодких, м'ясних, сирних ароматів на різних стадіях розщеплення сироваткових білків, після взаємодії з вуглеводами. Розглянуто вплив глибини протеолізу на подальше формування аромату з попередників. Встановлено, що продукти розщеплення молочного цукру в молочній сироватці грають не суттєву роль в процесах утворення аромату. На відміну від протеолітичних ферментів, використання лактази (β-галактозидази) не привело до змін ароматичної характеристики модифікованої сироватки. Збільшення концентрації лактулози, як потенційного попередника аромату в цукрово-амінних реакціях молочної сироватки, надає тільки солодкуватий відтінок та істотного не впливає на зміну аромату. Послідовно досліджені процеси утворення аромату в модифікованій молочній сироватці та апробована принципова схема ароматизованої харчової піни на її основі. Показано, що додавання хлористого натрію 5-10 % до кубового залишку після ректифікації ферментованої молочної сироватки значно підвищує стійкість аромату кінцевого продукту. Встановлено, що специфічний аромат молочної сироватки, який обмежує її використання в області продуктів харчування, піддається модифікації внаслідок використання нових підходів до реакцій з попередниками аромату. Розглянуто фіксація отриманих ароматів «супових-грибний», «бульйонний», «сирний» на масляну основу для подальшого концентрування і застосування.

Ключові слова*:* молочна сироватка, ароматичний дескриптор, ферменти, попередник, умови реакції, харчова піна.

Список літератури:

1. Жидков В.Е. Научно-технические основы биотехнологии альтернативных вариантов напитков из молочной сыворотки. Ростов н/Д: СКНЦ ВШ, 2000. 144 с.
2. Мельникова Е.И. Исследование биотехнологического потенциала творожной сыворотки: модификация химического состава, прогнозирование качества и новые технологические решения / дис. … докт. техн. наук: 05.18.07: защита 18.10.2007 / Воронеж: Воронежская государственная технологическая академия, 2007. 458 с.
3. Храмцов А.Г. Феномен молочной сыворотки. Санкт-Петербург: Профессия, 2011. 802 с.
4. Газохроматографический и микрогравиметрический анализ ароматобразующих компонентов молочной сыворотки / Коренман Я.И. и др. // Известия вузов. Химия и химическая технология. 2004. №. 47, Т. 10. С. 140-142.
5. Sensory and flavour characteristics of milk / Wolf I. V. et al // Milk and dairy products in human nutrition: production, composition and health. 2013. P. 310–337. https://doi.org/10.1002/9781118534168.ch15.
6. Mortenson M. A., Vickers Z. M., Reineccius G. A. Flavour of whey protein concentrates and isolates//International dairy journal. 2008. Vol. 6, № 18. P. 649-657. https://doi.org/10.1016/j.idairyj.2007.12.003.
7. Determining flavour and flavour variability in commercially produced liquid Cheddar whey / Whetstine M.C. et al // Journal of dairy science. 2003. Vol. 2, № 86. P. 439-448. https://doi.org/10.3168/jds.2012-5935.
8. Мусійчук О. Перспективи використання продукту переробки молочної сироватки // Товари та ринки. 2008. №1. С. 78-83.
9. Синенко Т.П., Дубова Г.Є. Характеристика ароматичних дескрипторів продуктів ректифікації молочної сироватки // Прогресивні техніка та технології харчових виробництв ресторанного господарства і торгівлі. 2019. Вип. 1 (29). С. 63-74.
10. Digital.NYC Weekly: веб-сайт. URL: http://www.digital.nyc/startups/skinnyeats. (дата звернення: 12.05.2019).
11. Горбатова К.К., Гунькова П.И. Химия и физика молока и молочных продуктов. Санкт-Петербург: ГИОРД, 2012. 336 с.
12. Cheese flavouring process: пат. 3072488 США/Watts J. J. C., Nelson J. H.;опубл. 8.01.1963.
13. Лактоза и ее производные / Синельников Б.М. и др. Санкт-Петербург: Профессия, 2007. 768 с.
14. Авдалян Г. В. Технология глюкозо-галактозного сиропа на основе кислотного гидролиза лактозы: автореф. дисс. на соискание уч. степени канд. техн. наук: 05.18.04. Москва: Всес. науч.-исслед. и конструкт. ин-т мясной пром-сти, 1990. 18 с.
15. Мусина О.Н., Лисин П.А. Сыворотка и продукты из нее: анализ патентной ситуации // Молочная промышленность. 2008. № 12. С. 79-80.
16. Свириденко Ю.Я., Абрамов Д.В., Свириденко Г.М. Продукты на основе ферментативного гидролиза лактозы и белков молочной сыворотки // Переработка молока. 2007. Т. 1, № 2. С. 56-57.
17. Циганков В.Г., Головач Т.Н., Курченко В.П., Бондарук А.М. Исследование пептидных ферментативных гидролизатов концентрата сывороточного белка коровьего молока для разработки продуктов питания для туризма и отдыха // Труды БГТУ. 2015. Вып. 174. С. 272-275.
18. Сидоров Ю.І. Розробка технології виробництва біологічно активної суміші амінокислот з молочної сироватки // Вісник Національного університету «Львівська політехніка». 2008. № 622. С. 88-95.
19. Направленный ферментолиз белков молочной сыворотки / Березкина К.А., и др. // Переработка молока. 2014. Т. 7, № 2. С. 20-22.
20. Закономерность гидролиза сывороточных белков экзо- и эндопротеиназами / Головач Т.Н. и др. // Труды Белорусского государственного университета. 2008. №3, Т. 1. С. 1-15.
21. Kühn J. Studies on interactions of milk proteins with flavour compounds: a thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Food Technology at Massey University, Palmerston North, New Zealand : Massey University, 2007. 230 p.
22. Glycomacropeptide and alpha-lactalbumin supplementation of infant formula affects growth and nutritional status in infant rhesus monkeys / Kelleher S.L. et al // American Journal of Clinical Nutrition. 2003. Vol. 77, № 5. P. 1261-1268. https://doi.org/1261-1268. 10.1093/ajcn/77.5.1261.
23. The structure of β-lactoglobulin and its similarity to plasma retinol-binding protein / Papiz M.Z. et al // Nature. 1986. № 324. P. 383-385. https://doi.org/10.1038/324383a0.
24. Boye J.I., Alli I. Thermal denaturation of mixtures of α-lactalbumin and β-lactoglobulin: a differential scanning calorimetric study // Food Research International. 2000. № 33. P. 673-682. https://doi.org/10.1016/S0963-9969(00)00112-5.
25. Курбанова М.Г. Ферментативный гидролиз молочных белков с использованием различных протеаз // Вестник КрасГАУ. 2010. № 40. С. 157-160.

26. Dixon M., Webb E.C.. Enzymes. New York: Academic Press, 1980. 1116 p. https://doi.org/10.1021/ed042pA486.3.
27. Грачева И.М., Кривова А.Ю. Технология ферментных препаратов. Москва: Эльсвар, 2000. 512 с.
28. Крусь Г.Н., Шалыгина А.М., Волокитина З.В. Методы исследования молока и молочных продуктов. Москва: Колос, 2000. 368 с.
29. Новокшанова А. Л., Неповинных Н. В., Абрамов Д. В. Исследование влияния гидролизата сывороточных белков на органолептические показатели основ кислородных коктейлей // Вестник Международной академии холода. 2016. № 2. С. 4-9. https://doi.org/10.21047/1606-4313-2016-15-2-4-9.
30. Ткаченко О.Б., Тринкаль О.В. Химимя ароматов вина // Харчова наука і технологія. 2015. Т. 1, № 30. С. 42-50.
31. Грень А.И., Высоцкая Л.Е., Михайлова Т.В. Химия вкуса и запаха мясных продуктов. Киев: Наукова думка, 1985. 100 с.
32. Вкусоароматическая активная композиция: пат. 2577409 Российская федерация. заявл. 07.07.2010; опубл. 20.03.2016, Бюл. № 8.
33. Худяков К.Ю., Азолкина Л.Н. Вопросы глубокой переработки молока при производстве мягкого сыра // От биопродуктов к биоэкономике: 2018 год: материалы II межрегиональной научно-практической конференции (с международным участием), 12-13 апр. 2018 г. Барнаул: Изд-во АлтГТУ, 2018. С. 264-267.