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**ANALYSIS OF CHEESES MADE BY WASTE-FREE TECHNOLOGY**<https://doi.org/10.15673/fst.v16i4.2539>**Correspondence:****M. Samilyk***E-mail:* maryna.samilyk@snau.edu.ua**Cite as Vancouver style citation**

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**Abstract.** The growing scarcity of resources and insufficient consumption of protein products by the majority of the world's population contributes to the rational use of all resources. Secondary milk raw materials are a source of protein and require mandatory processing. The study was aimed at developing a rational waste-free technology for processing raw milk into cheeses with high nutritional value and low cost. For research, three samples of cheeses were made: sample 1 – based on milk; sample 2 – based on cheese whey (0.3% citric acid solution was used for coagulation); sample 3 (caramel) – from a mixture of milk and whey (without curdling). Standard methods were used to determine organoleptic, physicochemical parameters. The nutritional value of the products was calculated according to the physicochemical parameters established during the study (mass fraction of proteins, fats, and carbohydrates). The proposed waste-free technology can be implemented in any cheese factory for the production of soft and hard cheeses. Products derived from whey are somewhat inferior in amino acid composition but have a relatively high value and organoleptic properties inherent in cheeses made from milk. The use of a citric acid solution for curdling makes it possible to reduce the duration of the process by 30 minutes and increase the yield of cheese by 5–7%. An evaluation of the organoleptic characteristics of the property showed that the cheese made from milk and whey does not differ. Cheese made from milk contains the largest mass fraction of proteins (17.2 g/100g) and fats (20 g/100g), the largest amount of carbohydrates is cheese based on a mixture of whey and milk (49 g/100g). Cheese is made from whey and has the lowest energy value (88.14 kcal). At the same time, the mass fraction of proteins in this cheese is higher than in cheese made from a mixture of whey and milk (sample 3). The results of the study of the amino acid composition showed that all cheeses have the same qualitative amino acid composition. According to the quantitative composition of amino acids, cheeses made from milk have the highest biological value.

**Key words:** waste-free technology, soft cheeses, cheese product, nutritional value, amino acid composition.

**Introduction. Formulation of the problem**

The population of the planet is constantly growing, which leads to a shortage of resources. At the same time, more than half of the people on Earth are not provided with enough food. In most countries, there is a low level of protein consumption. The food protein problem remains relevant in economic and social aspects. The economic aspect is explained by large volumes of production and costs for the production of protein foods. Speaking of the social component, it is worth noting that protein products are needed by all segments of the population, regardless of age and income level. Due to global climate changes, the amount of feed for meat and dairy cattle is decreasing [1]. Because of this, the cost of protein-containing products is constantly increasing. They become inaccessible to the least protected

categories of the population. An important reserve for obtaining additional protein of animal origin is the rational use of secondary dairy raw materials. By volume of production, the protein resources of secondary dairy raw materials occupy the first place in the world agro-industrial production.

**Analysis of recent research and publications**

Whey is of special importance among secondary dairy raw materials. The world production of serum is from 180 to 190·106 tons per year. Only 50% of this amount is processed and turned into food products and feed additives [2]. Due to inadequate approaches to bioconversion, a large amount of serum is disposed of annually. The disposal of serum without preliminary treatment leads to several environmental problems

associated with a significant burden on the ecosystem [3]. Whey contains a large number of organic substances such as lactose. The estimated chemical oxygen demand for biological purification of serum by oxidation is 60–80 kg/m<sup>3</sup>, and the biological oxygen demand is 35–45 kg/m<sup>3</sup> [4]. In addition to the aspect of environmental pollution, the release of whey leads to significant losses of potential food and energy, since about 55% of milk nutrients are transferred to whey [5].

The amount of whey is 85–90% of the volume of milk. It is obtained as a result of precipitation and removal of milk proteins during cheese making. Among the whey nutrients, the following are especially valuable: lactose (4.5–5.0%), soluble proteins (0.6–0.8%), lipids, and mineral salts [6]. The composition of serum depends on the cheese production process, the type of milk (sheep, goat, cow, or buffalo), as well as the amount of water, detergents, and disinfectants [3].

Cow milk proteins consist of 80% casein and 20% whey proteins [7]. Whey proteins have a greater biological value compared to casein. Their amino acid profile contains a high proportion of essential amino acids such as leucine, isoleucine, and valine. The listed amino acids are crucial for blood glucose homeostasis, metabolism, and nerve function [8].

A large number of studies are aimed at the development of technologies for food products, based on which whey is the main raw material [9,10]. About half of the whey is used in liquid form, 30% in the form of powder, 15% in the form of lactose and its by-products, and the rest in the form of whey protein concentrates [7]. The high content of lactose in whey makes it suitable for the production of biofuel [11,12]. Products obtained based on serum differ not only in high biological value but also in dietary properties. They are recommended in the diet of various population groups [13].

Value-added dairy products include whey powder, whey protein, and whey permeate. Among the important factors that make serum an attractive raw material for processing is the generally accepted regulatory status of safety (GRAS) [14].

From whey, you can make cottage cheese, albumen cheese, or ricotta cheese. At the same time, the secondary serum is formed as a by-product. The secondary product contains about 60% of the dry substances contained in the whey and is characterized by a lower protein concentration and a higher salt content due to the second stage of flocculation and the addition of salts during the production process [15]. It was established that whey proteins during denaturation at high temperatures (> 80°C) can adsorb water well, which leads to an increase in the yield of cheese. Cheeses based on whey proteins have increased moisture [16]. Adding whey proteins to cheese leads to an increase in moisture content by 8–10%, lactose by 23–31%, and long-chain fatty acids by 3–4% [17].

Adding whey proteins to cheeses made based on retentate improves their textural and functional

qualities [18]. The addition of ultra-high-pressure processed whey protein to processed cheeses gives them firmness but creates an undesirable sandy or grainy texture [19]. Whey protein concentrate is a source of sulfur-containing and branched-chain amino acids, lysine, threonine, and the total number of essential amino acids [8]. Hydrolyzing whey protein by enzyme or fermentation can generate useful bioactive peptides that regulate physiological functions. Whey protein is widely used in the food industry. Many newly developed whey protein peptide products with diverse biological activities are appearing on the commercial market or in research laboratories [20].

Cheeses are especially popular among whey products. Whey cheeses have a short shelf life, but the chemical composition and biological value are typical for cheeses [21]. The high nutritional value of serum has been proven by many researchers [22,23,24]. It has good organoleptic properties and is affordable.

Ricotta is among the most famous cheeses, manufactured and recycled. Ricotta is an Italian cheese with a high moisture content, made by direct acidification of whey and subsequent heating, during which protein denaturation and aggregation occur [25]. Ricotta is known to have a low-fat content (about 14%), so it can be recommended as a dietary product [26]. Low cost, lower fat content, and relatively high protein content make this cheese often used.

The analysis of literary sources shows that serum is a useful raw material and requires processing. It can increase the nutritional value of dairy products, but the question of the biological value of cheeses made based on whey has not been sufficiently studied.

In addition, it is worth paying special attention to the technology of cheese production, since not only their quality depends on it, but also their cost. At the core of any cheese-making technology is the curdling of proteins. The most common method of protein precipitation is the use of direct application cultures. At the same time, a high level of safety in the fermentation process and the quality of the finished product is ensured. Bacterial preparations based on lactobacilli are usually used [27]. The average duration of protein precipitation with the use of bacterial preparations is 5–6 hours. It is possible to reduce the duration of protein coagulation in the production of soft cheeses using a solution of citric acid. However, with this method, a large amount of serum proteins remains in the serum [28]. At the same time, when using cultures of direct application, technological regimes should be strictly observed at all stages of production, since violations at one stage cause violations at another [29].

**The purpose and tasks of the research.** The purpose of the study is to analyze some indicators of the quality and nutritional value of cheeses produced by waste-free technology based on milk and the derivatives of its processing.

Based on the set goal, the following **research tasks** were formulated:

- production of test samples of unripened cheeses using zero-waste technology;
- to investigate the organoleptic indicators of soft cheeses, some of their physical and chemical characteristics (protein, fat content);
- to determine the nutritional value of cheeses produced by waste-free technology;
- to analyze the amino acid composition of cheeses made according to the proposed technology.

**Research materials and methods**

Raw milk from the vivarium of the Sumy National Agrarian University (DSTU 3662:2018) was used for research.

Three samples of cheeses were produced: sample 1 - based on whole cow's milk; sample 2 – based on sweet curd whey (0.3% solution of citric acid was used for curdling); sample 3 - from a mixture of whole cow's milk and serum neutralized with a 25% NaOH solution (without curdling), obtained as a result of self-pressing of sample 1 and curdling of sample 2 (Fig. 1).

The organoleptic evaluation of cheeses was carried out according to a certain number of descriptors (Table 1) using a five-point scale based on averaged data. The tasting was conducted by 10 non-professional tasters. The results are presented in the form of a profile.

**Table 1 – Descriptors of organoleptic evaluation of cheeses**

Name of indicators	Characteristic
Appearance	The surface is clean without mechanical damage, elastic, and may have an impression of perforation
Taste and smell	Cheesy, sour milk, without extraneous tastes and smells, characteristic of a specific cheese. Allowed: slightly acidic, spicy, spicy, ammoniacal, salty with a slight bitterness
Consistency	Allowed: smear, slightly fragile or fragile, moderately dense
The color of the dough	From white to light yellow with a cream shade, it is uniform throughout the mass
Drawing	Dough without holes. The presence of small voids is allowed
Form	A rectangular bar, cylinder, or another shape

The protein content was determined by the accelerated semi-micro method (ISO 8968-3:2004, IDF 20-3:2004, IDT), and the fat content by the gravimetric method (ISO 1735:1987, IDT).

Carbohydrate content was determined by calculation, based on the difference between the mass fraction of dry substances and the sum of the mass fraction of proteins and fats (TU U 10.5-04718013-005:2020. Soft cheeses A2. Technical conditions).

The energy value of cheeses was calculated according to the following formula (TU U 10.5-04718013-005:2020 Soft cheeses A2. Technical conditions):

$$E = k_p \times (M_p + M_c) + k_f \times M_f \quad (1)$$

where  $E$  is the energy value, kcal;

$M_p$  – a mass fraction of protein, g/100 g of product;

$M_c$  – a mass fraction of carbohydrates, g/100 g of product;

$M_f$  – a mass fraction of fat, g/100 g of product;

$k_p = 4$  – coefficient of the energy value of 1 g of protein or 1 g of carbohydrates in the product, kcal/g;

$k_f = 9$  – coefficient of the energy value of 1 g of fat in the product, kcal/g.

Identification of the amino acid composition was carried out by the method of ion exchange column chromatography using the amino acid analyzer "BIOTRONIK" (Germany). To determine the total content of amino acids, a weight of 0.3 g of raw material was placed in a test tube with a ground stopper with a capacity of 50 ml, 10 ml of distilled water and 10 ml of concentrated hydrochloric acid were added, thoroughly mixed and left in a dry oven at 130°C for 8 hours. After the end of hydrolysis, the solution was filtered, and evaporated and the pH was adjusted to 2.2. 1 ml of buffer solution with a pH of 2.2 was added to 1 ml of the prepared sample, the mixture was passed through a membrane filter with a pore diameter of 0.45 μm. 50 μl of the purified sample was taken and introduced into the chromatographic ion exchange column of the analyzer.

Statistical processing of experimental studies was carried out by the method of mathematical analysis. Final results were expressed as mean ± standard deviation (SD) of measurements from three separate extracts, and measurements were performed in three different studies. Comparison of group means and significance of differences between groups were tested by Student's t-test. Statistical significance was set at  $p \leq 0.05$ .

**Results of the research and their discussion**

The production of soft cheeses and cheese products was carried out according to the zero-waste technology, which was developed independently, by summarizing typical rational technologies for the production of soft cheeses (Fig. 1). The peculiarity of this technology is that based on milk and the by-product of its processing, 2 types of soft cheeses are produced at once (sample 2, sample 3). A 0.3% solution of citric acid was used to precipitate milk proteins. The whey obtained after the separation of the cheese curds was subject to reprocessing according to the same scheme as the cheese made from whole milk.

Cooled, purified milk after temporary ripening was pasteurized at a temperature of 63°C for 30 minutes. Citric acid was added to hot milk in the form of a 0.3% solution (at the rate of 0.3 g per 1 liter of milk). It was stirred for 30 seconds and left alone to settle. The formed cheese curd was separated from the whey, cut into 2x2 cm cubes, and placed in cheese molds for self-pressing for 20 minutes.

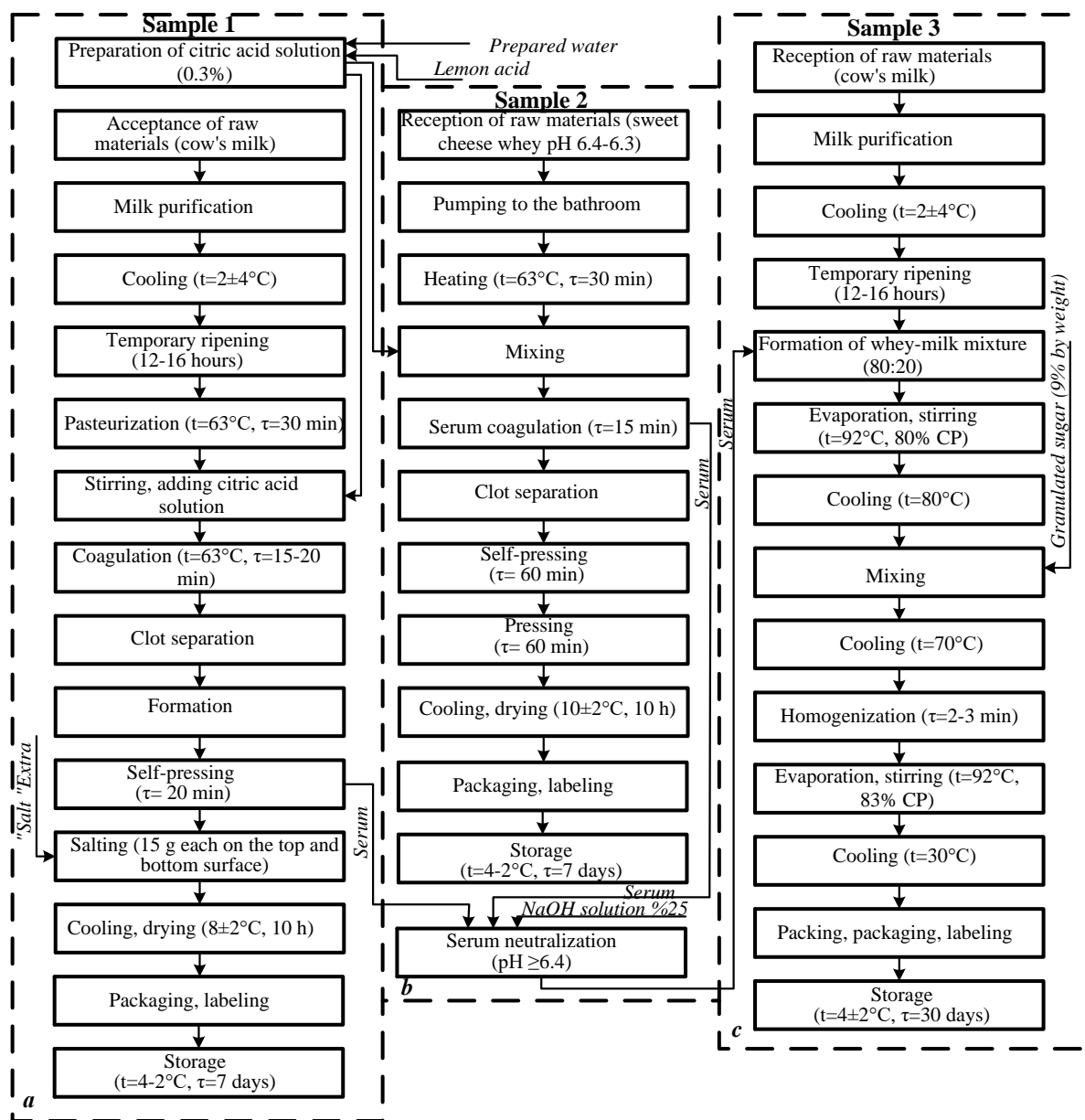


Fig. 1. Technological scheme for the production of soft cheeses: a – based on milk; b – based on serum; c – based on a mixture of milk and whey

The upper and lower surface of the cheese heads were sprinkled with "Extra" salt, cooled, and dried in a refrigerator for 10 hours. The whey separated from the curd was heated to a temperature of  $63^{\circ}\text{C}$  and a solution of citric acid was added. Precipitated whey proteins were formed, and left for self-pressing and pressing. All technological operations of cheese processing were similar to the technology of making cheese from milk.

The yield of cheese from milk was 17%, from whey – 4%. When applying the traditional technology of making soft cheeses based on milk and the direct introduction of bacterial starters, the yield of cheese is 10-12%. Thus, when using citric acid, the yield of cheese from whole milk increases by 5-7%. From the point of view of economic efficiency, the developed technology is more appropriate not only due to an

increase in the yield of the finished product but also due to a decrease in the duration of the process and a lower cost of citric acid compared to bacterial starters. When using bacterial starters and enzymes, the duration of curd formation in the production of soft cheeses is 35–40 min [30]. In the case of using a solution of citric acid, the setting time is reduced by 30 min, according to the typical technology, the setting time is 35–40 min [30]. Therefore, the total production time of soft cheese is reduced.

The whey obtained as a result of the production of soft cheeses was neutralized to  $\text{pH}=6.4$  with the help of a 25% NaOH solution and sent to the production of caramel cheese. For the production of caramel cheese, whey was mixed with milk in a ratio of 8:2, thickened to a dry matter content of 80%, granulated sugar was

added and evaporation was continued until the dry matter content was 83%.

Cheeses obtained from milk and whey had practically the same sensory properties (Fig. 2. a, b).



Fig. 2. Soft cheeses: a – based on milk, b – based on whey

According to the organoleptic evaluation, sample 1 (Fig. 2, a) using a solution of citric acid and milk was characterized by a pronounced cheesy, sour-milk taste, without extraneous tastes and smells, characteristic of soft fresh cheese. The surface is elastic, had minor mechanical damage, and isolated voids, with an imprint of perforation. The consistency is delicate and moderately dense. The color is white with a cream shade, uniform over the entire mass. Dough with small holes and voids. The shape is cylindrical.

The surface of sample 2 (Fig. 2. b), made from serum, had mechanical damage but was elastic with a perforation imprint. Detailed organoleptic assessment is presented in Fig. 3.

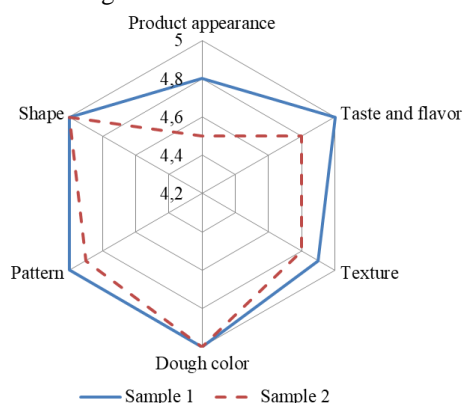


Fig. 3. Profilogram of organoleptic evaluation of cheeses

The taste of the experimental sample made based on milk (sample 1) is cheesy, sour milk, without extraneous tastes and smells. A sweeter taste was observed in sample 2. The consistency of test samples 1, and 2 is a smear, slightly brittle, moderately dense. The color of the dough is white with a creamy shade, uniform over the entire mass. Dough with small voids. The shape is cylindrical. Given that sample 1 was produced by a typical technology, based on a typical raw material, it was taken as a control when compared with a sample made based on serum. In terms of organoleptic properties, cheeses made from milk and whey, by the method of acid curdling, the shape and color of the dough correspond to the indicators characteristic of cheeses made with the direct introduction of bacterial starters. The rest of the indicators slightly differ from the requirements of the standard.

The cheese based on a mixture of whey and milk had a characteristic caramel taste, smell, dark brown color, and a thick smear consistency (Fig. 4).

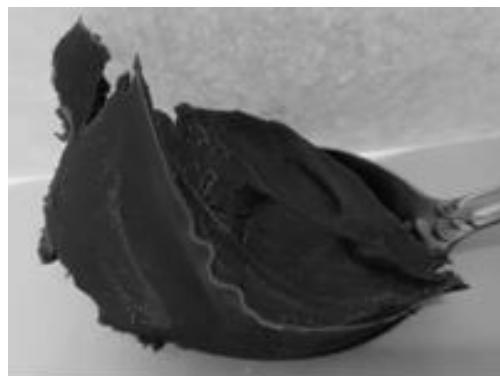


Fig. 4. Cheese based on a mixture of milk and whey

Due to the high-temperature treatment, the Maillard reaction occurs between lactose and amino acids. The main products of this reaction are melanoidin, which gives the cheese a special caramel color and aroma [31].

To calculate the energy value of products, an analysis of physicochemical indicators was carried out, the results are presented in Table 2.

Table 2 – Physico-chemical quality indicators of cheeses

Indicators, g/100 g	Sample 1	Sample 2	Sample 3
- a mass fraction of protein	17,2±0,08	8,06±0,07	6,7±0,08
- a mass fraction of fat	20,0±0,09	4,06±0,08	8,0±0,08
- a mass fraction of carbohydrates	1,6±0,08	4,84±0,08	49,0±0,09
Energy value, kcal	255,2	88,14	294,8

Cheese made from whey (sample 2) had a low energy value (88.14 kcal), but the mass fraction of fat in it is 15.94 g/100g less than in cheese made from whole milk (sample 1). Such cheese will be a good source of protein for people with special dietary needs. Cheese based on a mixture of whey and milk (sample 3) contained the largest amount of carbohydrates (49 g/100 g) and the highest energy value – 294.8 kcal.

The results of amino acid composition (Fig. 5) showed that cheese made from whey contains all the same amino acids as cheese made from milk. It is worth noting that the concentration of some amino acids in sample 2 was significantly lower than in sample 1: glutamic acid (by 1.33%), proline (by 1.13%), phenylalanine (by 0.58%), serine (by 0.53%), tyrosine (by 0.47%). Almost the same concentration of alanine (milk cheese contains 0.01% more than whey cheese), cystine and methionine (difference 0.07%), glycine (difference 0.08%), ammonia (difference – 0.09%). Cheese made from whey (sample 2) contains a large number of amino acids, including essential ones, g/100g: valine – 0.59; leucine – 1.15; isoleucine – 0.61; threonine – 0.52; methionine – 0.02; lysine – 0.78; phenylalanine – 0.37.

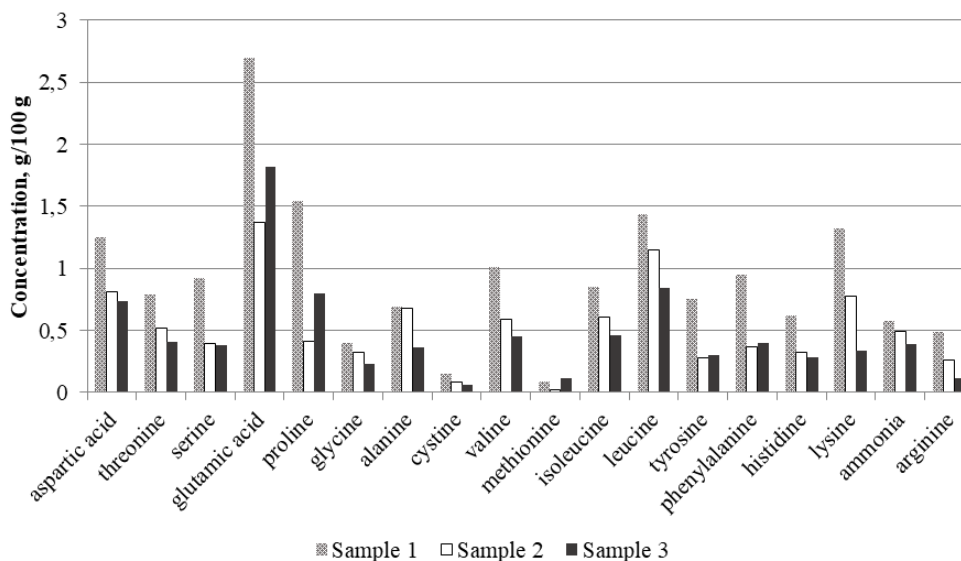


Fig. 5. Amino acid composition of cheeses

They also include amino acids that are especially useful for children and the elderly: arginine (0.26 g/100g), and histidine (0.32 g/100g). Arginine is involved in cleansing the liver and regulating the growth of muscle mass. Histidine affects the production of white and red blood cells, as well as the growth of muscles, and is the basis for the production of histamine, which is necessary for the regulation of sleep and wakefulness cycles, sexual function, and the production of the myelin sheath of nerve cells.

In cheeses made from a mixture of whey and milk, glutamic acid (1.82 g/100g, which is 0.45 g/100g more than in sample 2), leucine (0.84 g/100g), and aspartic acid (0.74 g/100g). Glutamic acid participates in protein and carbohydrate metabolism, stimulates oxidation processes, and promotes detoxification and removal of ammonia from the body.

In addition, more essential amino acid methionine was found in sample 3 than in samples 1 and 2 (by 0.02 and 0.09 g/100g, respectively). It has a good effect on the condition of the kidneys, reduces the toxicity of many poisonous substances, and helps restore liver functions.

Approbation of research results. The technology of non-waste production of cheeses based on milk and whey was tested in the conditions of D.V. Opryshko FOP.

### Conclusion

The proposed technology of complex processing of raw materials is waste-free and allows you to obtain three types of cheese: milk, whey, and a mixture of milk and whey. The use of a solution of citric acid for

curdling allows you to reduce the duration of the process by 30 minutes and increase the yield of cheese by 5-7%.

The organoleptic evaluation showed that cheese made from milk and whey practically does not differ in shape, dough color, pattern, and consistency. Cheese made from whey had a sweeter taste, which is not characteristic of soft cheeses. The cheese based on a mixture of whey and milk had a characteristic caramel taste, smell, dark brown color, and a thick smear consistency.

Cheese made from milk contained the highest mass fraction of proteins (17.2 g/100g) and fats (20 g/100g), the highest amount of carbohydrates – cheese based on a mixture of whey and milk (49 g/100g). Cheese made from whey turned out to be the most balanced in terms of the ratio of proteins, fats, and carbohydrates.

The lowest energy value was cheese made from whey (88.14 kcal), and the highest – the cheese was based on a mixture of whey and milk (294.8 kcal).

The results of the amino acid composition showed that all cheeses have the same qualitative amino acid composition. According to the quantitative composition of amino acids, cheeses made from milk have the highest biological value. A slightly smaller amount of amino acids is found in cheeses made from whey. Almost the same amount of alanine (0.69 and 0.68 g/100g, respectively) and glycine (0.4 and 0.32 g/100g, respectively) was found in samples 1 and 2. In cheeses made from a mixture of whey and milk, the highest amount of glutamic acid was found at 1.82 g/100g, which is 0.45 g/100g more than in cheese made from whey.

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## АНАЛІЗ СИРІВ, ВИГОТОВЛЕНИХ ЗА БЕЗВІДХОДНОЮ ТЕХНОЛОГІЄЮ

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**Анотація.** Зростання дефіциту ресурсів та недостатнє споживання білкових продуктів більшістю світового населення сприяє раціональному використанню всіх ресурсів. Вторинна молочна сировина є джерелом білка і потребує обов'язкової переробки. Дослідження було спрямоване на розробку раціональної безвідходної технології переробки молочної сировини на сири з високою харчовою цінністю та низькою собівартістю. Для досліджень було виготовлено три зразки сирів: зразок 1 – на основі молока; зразок 2 – на основі підсирної сироватки (для зсідання використовували 0,3% розчин лимонної кислоти); зразок 3 (карамельний) – із суміші молока та сироватки (без зсідання). Для визначення органолептичних, фізико-хімічних показників СІРІВ використовували стандартні методики. Харчову цінність продуктів розраховували за встановленими в процесі дослідження фізико-хімічними показниками (масовою часткою білків, жирів та вуглеводів). Запропонована безвідходна технологія може бути впроваджена в умовах будь-якої сироварні з виробництва м'яких та твердих сирів. Отримані із сироватки продукти дещо поступаються за амінокислотним складом, але мають відносно високу харчову цінність та органолептичні властивості, притаманні сирам виготовленим із молока. Застосування розчину лимонної кислоти для зсідання дозволяє знизити тривалість процесу на 30 хв, збільшити вихід сиру на 5–7%. Оцінка органолептичних показників якості показала, що сир виготовлений із молока та сироватки практично не відрізняються. Сир виготовлений із молока містить найбільшу масову частку білків (17,2 г/100г) та жирів (20 г/100г), найбільшу кількість вуглеводів – сир на основі суміші сироватки та молока (49 г/100г). Сир виготовлений із сироватки, він має найменшу енергетичну цінність (88,14 ккал). Разом з цим, масова частка білків в цьому сирі вища, ніж у сирі виготовленому із суміші сироватки та молока (зразок 3). Результати дослідження амінокислотного складу показали, що всі сири мають однаковий якісний амінокислотний склад. За кількісним складом амінокислот найвищу біологічну цінність мають сири, виготовлені із молока.

**Ключові слова:** безвідходна технологія, м'які сири, сирний продукт, харчова цінність, амінокислотний склад.