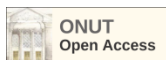


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AUTHENTIC CHEESES: MICROBIOLOGY, STARTERS, AND TECHNOLOGICAL ASPECTS OF PRODUCTION<https://doi.org/10.15673/fst.v17i3.2654>**Correspondence:****S. Danylenko**
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<http://creativecommons.org/licenses/by/4.0>**Introduction. Formulation of the problem**

Cheese is a generic term for a group of fermented dairy products produced worldwide, known for their diverse flavors, textures, and forms. The dairy industry is one of the leading sectors in the global economy [1]. Furthermore, this sector of food industry can be considered one of the most developed and ancient. There is compelling evidence of the emergence of cheese production and human use of milk dating back

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Abstract. The work is dedicated to the varieties, microbiological peculiarities and technological aspects of production of certain types of authentic cheeses. The purpose of work is to determine the microbiological peculiarities of authentic cheeses, to analyze their varieties and microbiota, to define the biotechnological peculiarities of production of certain types of authentic cheeses. Monographic, constructive, causal analysis and logical generalization methods were used. Cheese is the most popular food product in the world; there are 5,000 varieties of cheese. Although standard cheeses produced on large-scale productions are the most popular and widespread, authentic cheeses are also popular due to their unique organoleptic properties. Many factors influence the unique characteristics of authentic cheeses, the main of which are the quality of milk, its microbiological and chemical composition, and the technological methods used in cheese-making. All authentic cheeses are characterized by the presence of lactic acid bacteria, but the use of untreated milk sometimes leads to the presence of foodborne pathogens in the final product. Certain authentic cheeses have a complex microbiota, which complicates their production and the creation of starter cultures. However, for many cheeses, especially those like feta, there are now technological approaches to production, and most research is aimed at achieving an authentic taste and improving the organoleptic properties of the final product. Analysis of the quantitative and qualitative composition of the fermenting microbiota and the technological features of different types of traditional cheeses makes it possible to determine the composition of new fermenting compositions that are inherent to a particular product and to choose ways to increase the efficiency of cheese production.

Key words: cheeses, production, microbiology, biotechnology, lactic acid bacteria, starter culture.

to 7,000 years BC, along with the domestication of cattle, sheep, and goats [2,3]. Over time, from about the 3rd millennium BC., people started not only using raw milk but also conducting primary processing of this product [4]. Archaeological research indicates the production of soft cheese as early as 2,500 years ago [5]. Over time, dairy and other products of the industry gained popularity due to their nutritional and organoleptic properties, and the variety of the market continued to expand. However, the most well-known

and widely consumed groups of dairy products are those that have been created since ancient times, such as kefir, yogurt, soft cheese, sour cream, etc. [4,6]. The history of cheese production dates back over 4,000 years, starting in Arab countries and later becoming popular in Europe. Cheeses differ from each other in terms of technological parameters, microbiological and biochemical processes during production, chemical composition, shape, and weight. The abundance of names is linked to historical, national, and geographical characteristics of the origin of cheeses in different countries and among different cultures [7,8].

Some of the most well-known and widely consumed dairy products are various types of cheese, including hard and soft varieties [9]. In general, cheese is a generic term for a large group of dairy products made from fermented milk, produced worldwide. Depending on the location and production technology, cheeses can have different structures, tastes, and textures [10]. Various studies on cheeses and their varieties indicate a significant diversity of this product. For example, a study [11] describes approximately 400 varieties of cheese, while another one [12] classifies 510 different types. More recent research indicates the existence of 750 cheese varieties [13].

Many modern kinds of cheese were created in European monasteries, and the inter-monastery exchange contributed to the spread of these varieties and the creation of new ones. Some of the earliest varieties include Gorgonzola (Italy, 897 AD), Roquefort (France, 1070 AD), Cheddar (England, 1500 AD), and Gouda (Netherlands, 1697 AD) [10].

Today, cheese consumption around the world is quite significant, especially in France, Germany, Luxembourg, and Iceland. For France, the per capita cheese consumption as of 2023 stands at approximately 23 kg per year, while the average for European Union countries varies around 18.3 kg per year [14]. In Ukraine, the per capita cheese consumption was estimated as 5 kg per year in 2020 [15]. Although the figures vary, consumption and, consequently, production of various cheeses tends to increase, which is a favorable factor for creating new products and introducing non-standard cheese varieties into industrial production [16]. Today, the production of many cheese varieties, especially hard cheeses, is established on an industrial scale [9]. However, there is active development in the direction of artisanal production of many cheeses, including those with non-standard recipes, as well as traditional or authentic varieties [17,18]. Artisanal and sometimes homemade production of various authentic cheeses is quite widespread in many regions of Ukraine, especially in Zakarpattia and Lviv regions [17,19]. Such production is considered a part of gastronomic tourism and attracts to the cheese-making industry in Ukraine, which is a

positive factor for the economy and the food industry sector [19].

There are over 5000 varieties of cheese. Considering such species diversity, we can conclude that there is a significant demand and popularity for various cheeses. The research on the properties and production technologies of authentic cheeses, as well as improving the technological methods of their production, including the creation of starter cultures, is a highly relevant and promising area of research in dairy biotechnology.

The **purpose** of this study is to provide an analytical review of scientific literature regarding certain varieties, microbiological, and technological characteristics of authentic cheeses production.

To achieve the set objective, the following **tasks** were formulated in the study:

- 1) to describe the main varieties of authentic cheeses and their characteristics;
- 2) to analyze the microbiota specifics of authentic cheeses, identifying unique microbial cultures associated with authentic cheeses;
- 3) to illuminate the technological peculiarities in the specific types of authentic cheeses production.

Analysis of recent research and publications

Cheese is considered the most important and diverse group of dairy products and represents a complex biochemical system. Furthermore, cheese production currently accounts for 35% of the world's total milk production [20]. Since this group of products is quite large, various classification systems for cheeses have been established, including traditional classifications based on their rheological properties and firmness. Cheeses are also categorized into "super-families", such as rennet cheeses, acid cheeses, those made by heat and acid coagulation, as well as concentrated and crystallized cheeses [21]. A more detailed and contemporary classification is presented in Figure 1.

Traditional or authentic cheeses are of particular interest as they have their own recipes, organoleptic properties, methods of preparation or production, and the area where they are produced [23]. Such cheeses not only have gastronomic value but are also considered the cultural heritage and the result of accumulated knowledge passed down for generations [24,25]. Traditional cheeses are quite popular, especially in Europe. This popularity is due to high consumption level, local cuisine characteristics, organoleptic (especially taste) properties of the cheese, and the consumers' associations with the quality and authenticity of such products [25].

The main characteristic of authentic cheeses, which impacts their final organoleptic properties, is the rich microbial composition specific to each cheese variety [26,27].

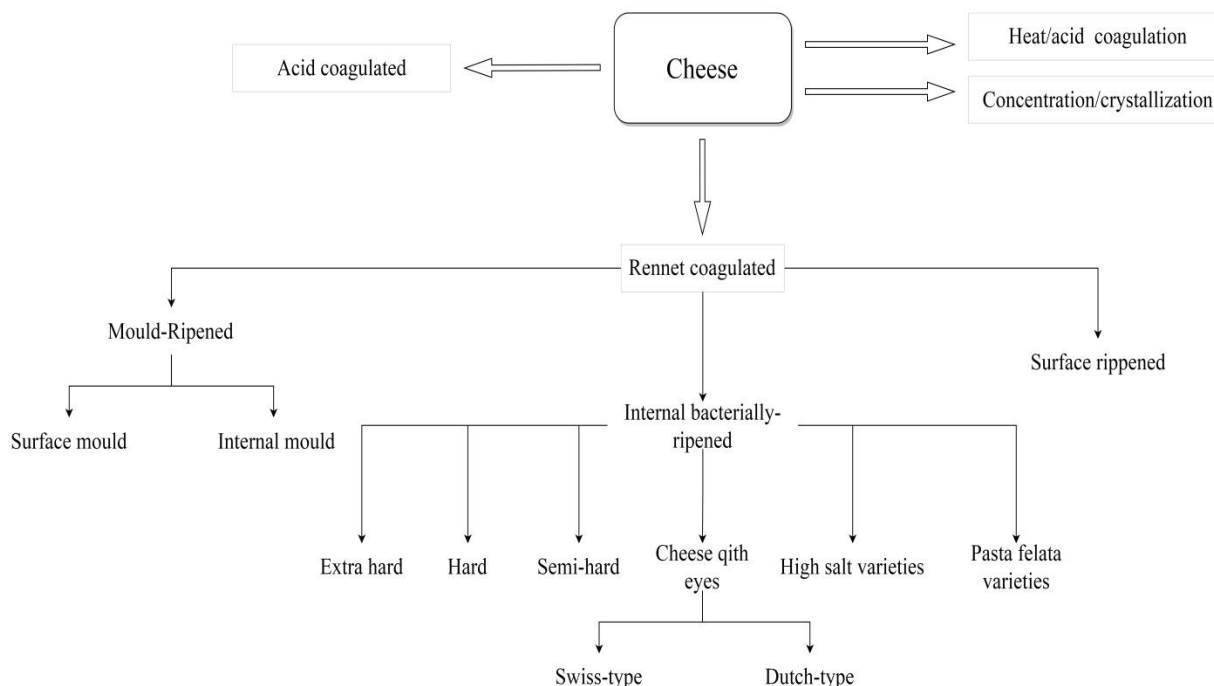


Fig. 1. General scheme of cheese classification [20-22]

Typically, increased biodiversity is achieved through the use of organic fresh milk (from cows, goats, buffaloes, and sheep), specialized equipment, and the cheese-making process itself. Another factor that can influence the microbiota of authentic cheese is the climate and the quality of milk, which are directly related to the geographical location [27].

In addition to their unique organoleptic properties, certain research indicates the possibility of modulating and restoring the gut microbiota in humans after consuming authentic cheeses made from raw milk compared to cheeses made from pasteurized milk [28,29]. It is also noted that traditional cheeses contain 5-10 times more conjugated linoleic acid (CLA) than ordinary cheeses [30]. CLA improves the lipid profile of the blood [31] and positively affects the body's immune system [32,33]. The presence of CLA in traditional cheeses is associated with the use of raw milk, the location of pastures, and the diet of the livestock [29].

Although there are significant advantages in the production and consumption of authentic cheeses, there are also drawbacks. One of the main concerns is the potential contamination of the product or initial contamination of the raw materials and equipment, especially in large-scale production. However, it should be noted that a significant portion of the microbial composition inherent to cheese has bacteriostatic effects *in vitro* against foodborne pathogens such as *Listeria monocytogenes* [34,35], *Staphylococcus aureus* [36], *Klebsiella pneumoniae*, *Salmonella typhimurium*, *Bacillus subtilis*, and *Pseudomonas aeruginosa*, which is further described in works [29,37,38]. It's also important to

consider the presence of antimicrobial components in raw milk, such as lactoferrin, lactoperoxidase, immunoglobulins, lysozyme, and free fatty acids [29].

Based on the above information, it can be stated that the authentic cheeses offer several advantages in comparison with ordinary ones. The complexity, and in some cases, the impossibility of producing them on an industrial scale due to the lack of necessary raw materials, non-compliance with technological specifics, and the reduction of microbial biodiversity in the final product makes the preservation of traditional recipes and cultural heritage challenging. Therefore, one potential way to preserve traditional recipes and cultural heritage is to support small local cheese dairies and craft production of authentic cheeses.

Diversity of Authentic Cheeses. Authentic cheeses are found all over the world but vary for a specific region or locality of a particular country. It can be said that European countries have the largest variety of authentic cheeses. Authentic cheeses are not only a culinary product but also an essential element of traditional cuisine, which is part of the cultural heritage of a region or country [39]. Today, due to changes in lifestyle, industrialization, and economic globalization, there is a risk of the disappearance of authentic food products, including cheeses [23].

To protect unique traditional dishes, food products, and special product names, the European Union has created geographical indications (GI), as well as labeling schemes such as protected designation of origin (PDO) and protected geographical indication (PGI), which are used for food products and wines [40]. For alcoholic

beverages, GIs are used separately. The GI, PDO, and PGI system establishes intellectual property rights for specific products whose quality is directly associated with the place of their production. It is also possible to grant the status of traditional specialty guaranteed (TSG), which highlights traditional aspects, such as the method of production or the composition of the product, without being tied to a geographical area, but which protects the product from falsification [40,41].

According to the analysis [40], as of 2017, there were a total of 1,388 authentic products registered, with 238 registrations related to cheeses. As of today, according to the eAmbrosia legal register, 255 cheeses are included. The results of the analysis are presented in Figure 2. According to the data obtained, the majority of registered authentic cheeses are from France and Italy, with the fewest from Belgium, Ireland, Hungary, and Cyprus.

Although the statuses described above provide comprehensive protection for authentic products, there is still a significant portion of unregistered cheeses, especially in post-Soviet countries, the Caucasus region, the Balkan Peninsula, and the Eastern Mediterranean [23,24]. Remarkably, these are the regions where dairy farming, production, and consumption of many dairy products (such as sour cream, kefir, yogurt) are characteristic, as compared to Western European countries [39].

Among the authentic cheeses of the Eastern Mediterranean, one of the most important groups consists of high-salt or brined cheeses. These are typically white brined cheeses, pasta filata-type cheeses, and others [24]. Some of the most popular authentic cheeses in the region include feta, halloumi, and bals (Greece) [43,44], telemea (Greece, Romania), white brined cheese (Bulgaria, North Macedonia), mohant (Slovenia), Vlašić cheese (Bosnia and Herzegovina) [24], tulum, beyaz peynir, edirne peyniri (Turkey) [45,46], domiati, mish (Egypt), akawi (Lebanon) [24], kefalotyri and kefalograviera (Cyprus, Greece) [44], chavdar (Bulgaria) [47]. For the countries of the Caucasus, there are authentic brined cheeses such as lorri (Armenia), bryndza (Azerbaijan, Northern Caucasus), sulguni, and Imeretian cheese (Georgia) [48].

Central and Eastern European countries are also known for their variety of authentic cheeses, but just as for the countries of the Mediterranean and the Caucasus, most of their authentic cheeses are brined [49]. One of the most well-known and widespread cheeses in the region is bryndza, but its preparation and microbiological characteristics differ from country to country. Bryndza is popular in Poland (with the PDO status of Bryndza Podhalańska) [50], Slovakia (with the PGI status of Slovenská bryndza) [51], Ukraine (called Hutsul sheep bryndza and Hutsul cow bryndza) [52-54], Romania, and Moldova [55]. For Poland and Slovakia, oscypek (Polish oscypek or Slovak oštiepok) is another typical cheese that is smoked at the end of preparation. While both cheeses share the same name, Polish and Slovak versions are distinct due to their preparation methods, and both are registered in eAmbrosia as Oscypek [56] and Slovenský oštiepok [57] with PDO and PGI statuses, respectively. Lesser-known authentic cheeses in the region include redykolka and golka (Poland) [50], bunz, buts, or bundz (Poland, Ukraine) [50,52], parenica (Slovakia) [58], urda or vurda (Ukraine) [59].

The Carpathian region is naturally considered a center of traditional cheesemaking in Ukraine, due to its unique geographical conditions and the preservation of traditional recipes and cheesemaking methods. One of the common cheeses in this region is brined cheese, known as "bryndza", as well as "vurda" and "butz". Bryndza can be either fresh or smoked, and it transforms into brined cheese after salting to enable long-term storage.

For centuries, men have been traditionally responsible for making bryndza in the Carpathian Mountains in summer, following a technique passed down through generations. To make bryndza, rennet, also known as "gleg" or "rinzak", is added to sheep's, goat's, or cow's milk. The quality of this rennet significantly affects the cheese's flavor. The milk coagulates under the influence of the rennet, forming a cheese curd, which is then broken into small pieces, drained, and collected. At this stage, the cheese is called "budz". The budz is then hung over a container or placed in the sun to drain the excess liquid.

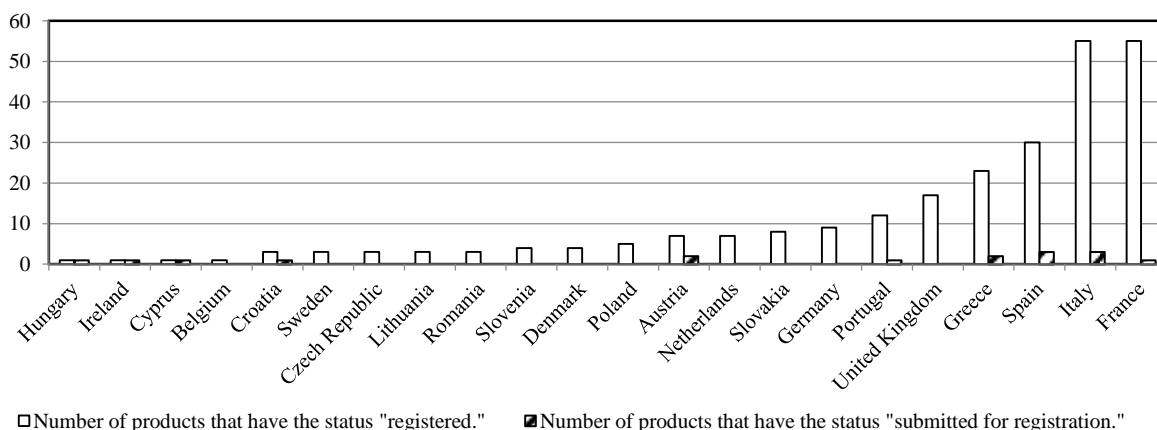


Fig. 2. Number of EU products with PDO or PGI status, according to eAmbrosia data [42]

After the cheese mass is removed from the container, a liquid by-product – whey – remains there and is used to make vurdza cheese. After formation of vurdza, there also remains a liquid called "zhentitsa".

To turn budz into brined cheese, it is kept for a week. Subsequently, it is mashed with butter, generously salted, and kept under pressure for a month. The brined cheese is compactly packed into special wooden containers and can be stored for several years.

In November 2019, the Ministry of Economic Development, Trade, and Agriculture of Ukraine issued a certificate of registration for the right to use the registered designation of origin for "Hutsul sheep bryndza". The geographical indication application was submitted by the public association "Association of Producers of Traditional Carpathian High-Mountain Cheeses" in December 2018. Hutsul sheep bryndza is made in high-mountain pastures (polonynas) from sheep's milk, following traditional practices that date back to the 15th century. The production area covers Zakarpattia and Ivano-Frankivsk regions, and a part of Chernivtsi region. The certificate was issued in accordance with the "Law of Ukraine on the Protection of Rights to Indication of Origin of Goods"[60].

Microbiological Characteristics of Authentic Cheeses. According to the analysis of data regarding the diversity of authentic cheeses, it is evident that a significant portion of them belongs to rennet-coagulated brined cheeses. For such cheeses, the microbiological composition of the bacterial starter culture used in cheese production is of great importance, as it induces biochemical changes during the cheese maturation process, shaping the texture, aroma, and flavor of the final product [61].

In the production of authentic cheeses, unprocessed raw milk is most commonly used. Therefore, the milk's microbiota often has the most significant influence on the quality and organoleptic properties of the finished cheese [29]. Depending on the type of milk used, authentic cheeses can be categorized into those made from goat's milk, sheep's milk, cow's milk, or mixed milk (sheep and cow) [43,62]. The type of milk used for cheese production not only affects the microbiological characteristics of the final product but also its structural and mechanical properties, as demonstrated in studies [62]. Furthermore, milk used for cheese production must be suitable for cheesemaking, meaning it should have a high casein content, which, to some extent, depends on the breed of cows, as demonstrated in research [63].

Today, there is a significant amount of research on the impact of milk on the final product, with most of these studies focusing on authentic cheeses from Greece, Slovenian bryndza, and Polish oscypek. The typical microorganisms found in authentic cheeses are presented in Table 1.

In the study [43], the authors compare the microbiota of authentic Greek cheese "gidotyri", made manually and industrially. For authentic cheese, a more diverse range of microorganisms was found, including the following:

Hafnia alvei, *Leu. mesenteroides* subsp. *mesenteroides*, *Leu. mesenteroides* subsp. *cremoris*, *Leu. mesenteroides* subsp. *dextranicum*, *Lo. coryniformis* subsp. *torquens*, *Carnobacterium maltaromaticum*, *Enterobacter hormaechei* subsp. *hoffmannii*. In addition to these, some milk contaminant bacteria such as *St. aureus* subsp. *aureus*, *Bacillus mycoides*, *A. colistiniresistens*, and so on were observed in small quantities.

Using specific examples of certain cheeses, especially Greek "batos" and Slovenian "bryndza", which are made only in spring and summer, changes in the microbiota of the finished product were demonstrated depending on the time of cheese production [44,64,65]. For example, "batos" made in the spring contains *Lc. lactis* subsp. *lactis*, *Lpb. paraplantarum*, *Lpb. pentosus*, *E. faecalis*, *E. faecium*, *E. durans*, and *Pediococcus* spp. Meanwhile, summer cheese samples contain *Lcb. paracasei* subsp. *paracasei*, *Lpb. paraplantarum*, *E. faecalis*, *E. faecium*, and *E. pseudoavium* [44]. "Feta" cheese, made from raw sheep's milk, has an ever-changing microbiota, which evolves during the maturation process. However, after 60 days of maturation, the most common microorganisms are representatives of lactic acid bacteria (LAB): *Lpb. paraplantarum*, *Lcb. paracasei* spp. *paracasei*, *Lcb. paracasei* spp. *tolerans*, *Lpb. plantarum*, *Llb. buchneri*, and *Lvb. brevis* [44,47].

For authentic white brined cheeses in Turkey, different microbiological characteristics are typical for each province. For example, in the province of Bursa (eastern Turkey), authentic white brined cheeses show a significant number of LAB (up to 2.2×10^8 CFU/g), low amounts of yeast and mold (up to 5.4×10^4 CFU/g), and coliforms (up to 1.3×10^2 CFU/g). In contrast, the province of Erzurum (western Turkey) shows high levels of total aerobic microorganisms (up to 2.4×10^9 CFU/g), significant yeast counts (2.6×10^6 CFU/g), and coliforms (2.8×10^5 CFU/g) in white brined cheeses [45]. Furthermore, *Enterococcus* species, such as *E. durans*, *E. faecium*, and *E. hirae*, are common in many white brined cheeses in Turkey [78].

Polish cheeses, especially authentic oscypek, exhibit significant microbiological biodiversity. For finished and smoked "oscypek," the most characteristic bacteria are of the genus *Lactococcus* (up to 80%), *Streptococcus* (up to 15%), *Leuconostoc*, and *Lactobacillus* [73]. Additionally, yeasts of the genera *Saccharomyces*, *Torulasporea*, and *Yarrowia* are present [72,73]. Furthermore, certain microorganisms such as *Escherichia coli* and *Clostridium perfringens* can also be found [74].

Although brynza is popular in many countries, each country and region of production exhibits a distinct microbiological composition. In a study [64], the authentic Moldovan brynza, produced from various types of milk, had a significant variety of LAB (Lactic Acid Bacteria), including *Lactococcus* spp., *Lactobacillus* spp., *Streptococcus* spp., *Leuconostoc* spp., and *Enterococcus* spp., as well as yeasts like *Yarrowia* spp. and *Kluveromyces* spp. This diversity is more detailed in Table 1.

Table 1 – Microbiota of specific authentic cheese varieties

Country of origin	The name of the cheese	Inherent microorganisms	Source
Greece	Hideous	<i>Enterobacter hormaechei</i> subsp. <i>hoffmannii</i> , <i>Hafnia alvei</i> , <i>Lc. cremoris</i> subsp. <i>tractae</i> , <i>Lc. lactis</i> subsp. <i>hordniae</i> , <i>Lc. lactis</i> subsp. <i>lactis</i> , <i>Lcb. rhamnosus</i> , <i>Leu. mesenteroides</i> subsp. <i>cremoris</i> , <i>Leu. mesenteroides</i> subsp. <i>dextranicum</i> , <i>Leu. mesenteroides</i> subsp. <i>mesenteroides</i> , <i>Leu. suionicum</i> , <i>Lmb. fermentum</i> , <i>Lo. coryniformis</i> subsp. <i>torquens</i> , <i>Lpb. argentoratensis</i> , <i>Lpb. paraplantarum</i> , <i>Lpb. pentosus</i> , <i>Lpb. pingfangensis</i> , <i>Marinilactibacillus psychrotolerans</i> , <i>Str. thermophilus</i>	[43]
	Batsos	<i>E. durans</i> , <i>E. faecalis</i> , <i>E. faecium</i> , <i>E. pseudoavium</i> , <i>Lc. lactis</i> subsp. <i>lactis</i> , <i>Lcb. paracasei</i> subsp. <i>paracasei</i> , <i>Lpb. paraplantarum</i> , <i>Lpb. pentosus</i> , <i>Pediococcus</i> spp.	[44]
	Feta	<i>Lpb. paraplantarum</i> , <i>Lcb. paracasei</i> subsp. <i>paracasei</i> , <i>Lcb. paracasei</i> subsp. <i>tolerans</i> , <i>Lpb. plantarum</i> , <i>Llb. buchneri</i> , <i>Lvb. brevis</i>	
Turkey	White pickled cheeses	Bacteria: <i>E. durans</i> , <i>E. faecalis</i> , <i>L. helveticus</i> , <i>Lc. cremoris</i> , <i>Lc. lactis</i> , <i>Lcb. casei</i> , <i>Lmb. fermenti</i> , <i>Lpb. plantarum</i> , <i>Lvb. brevis</i> , <i>Str. thermophilus</i> Yeast or molds: <i>Cladosporium herbarum</i> , <i>Geotrichum candidum</i> , <i>Mucor</i> spp., <i>Penicillium roqueforti</i> , <i>Penicillium verrucosum</i> var. <i>cyclopium</i>	[45]
Moldova	Brynza	Bacteria: <i>Enterococcus</i> spp., <i>L. delbrueckii</i> , <i>Lc. lactis</i> subsp. <i>cremoris</i> , <i>Lc. lactis</i> subsp. <i>lactis</i> , <i>Lcb. casei</i> , <i>Lcb. paracasei</i> , <i>Lcb. rhamnosus</i> , <i>Leuconostoc</i> spp., <i>Lmb. fermentum</i> , <i>Lpb. plantarum</i> , <i>Lvb. brevis</i> , <i>Str. thermophilus</i> Yeast or molds: <i>Kluyveromyces</i> spp., <i>Yarrowia</i> spp.	[64]
Mongolia	-	Bacteria: <i>Brochothrix</i> spp., <i>Carnobacterium</i> spp., <i>Flavobacterium</i> spp., <i>Hafnia</i> spp., <i>Lactobacillus</i> spp., <i>Lactococcus</i> spp., <i>Obesumbacterium proteus</i> , <i>Pseudomonas</i> spp., <i>Serratia</i> spp., <i>Streptococcus</i> spp. Yeast or molds: <i>C. sake</i> , <i>C. zeylanoides</i> , <i>Dipodascus geotrichum</i> , <i>Issatchenkia orientalis</i> , <i>Kazachstania unisporea</i> , <i>Kluyveromyces marxianus</i> , <i>Pichia fermentans</i> , <i>Trichosporon asteroides</i>	[65]
Kazakhstan	-	<i>A. baumannii</i> , <i>E. casseliflavus</i> , <i>E. durans</i> , <i>E. faecalis</i> , <i>E. faecium</i> , <i>L. delbrueckii</i> , <i>L. gasseri</i> , <i>L. helveticus</i> , <i>Lc. lactis</i> , <i>Lcb. paracasei</i> , <i>Leu. lactis</i> , <i>Leu. pseudomesenteroides</i> , <i>Lmb. fermentum</i> , <i>Lpb. plantarum</i> , <i>Lvb. brevis</i> , <i>Ochrobactrum lupine</i> , <i>P. acidilactici</i> , <i>P. pentosaceus</i> , <i>Str. thermophilus</i>	[66, 67]
Slovakia	Brynza	Bacteria: <i>A. baumannii</i> , <i>A. tandoii</i> , <i>Bacillus pumilus</i> , <i>Citrobacter braakii</i> , <i>Citrobacter koseri</i> , <i>E. faecalis</i> , <i>E. faecium</i> , <i>E. hirae</i> , <i>Enterobacter cloacae</i> , <i>Enterobacter ludwigii</i> , <i>Esch. coli</i> , <i>Hafnia alvei</i> , <i>Klebsiella oxytoca</i> , <i>Klebsiella pneumoniae</i> subsp. <i>ozaenae</i> , <i>Klebsiella pneumoniae</i> ssp. <i>pneumoniae</i> , <i>L. johnsonii</i> , <i>L. taiwanensis</i> , <i>Lc. lactis</i> , <i>Lc. lactis</i> ssp. <i>lactis</i> , <i>Lc. lactis</i> subsp. <i>cremoris</i> , <i>Lcb. paracasei</i> , <i>Leu. mesenteroides</i> subsp. <i>cremoris</i> , <i>Leu. mesenteroides</i> subsp. <i>mesenteroides</i> , <i>Leu. pseudomesenteroides</i> , <i>Lmb. fermentum</i> , <i>Lpb. paraplantarum</i> , <i>Lpb. plantarum</i> , <i>Lpb. plantarum</i> subsp. <i>argentoratensis</i> , <i>Lpb. plantarum</i> subsp. <i>plantarum</i> , <i>Lvb. brevis</i> , <i>Microbacterium liquefaciens</i> , <i>P. acidilactici</i> , <i>Paucilactobacillus suebicus</i> , <i>Raoultella ornithinolytica</i> , <i>Schleiferilactobacillus harbinensis</i> , <i>Serratia liquefaciens</i> , <i>St. aureus</i> ssp. <i>aureus</i> , <i>Staphylococcus pasteurii</i> , <i>Stenotrophomonas maltophilia</i> Yeast or molds: <i>Aspergillus fumigatus</i> , <i>C. catenulata</i> , <i>C. krusei</i> , <i>C. lusitaniae</i> , <i>C. rugosa</i> , <i>C. utilis</i> , <i>Dipodascus geotrichum</i> , <i>Dipodascus silvicola</i> , <i>Mucor circinelloides</i> , <i>Penicillium</i> spp., <i>Pichia cactophila</i> , <i>Rhizopus</i> spp., <i>Yarrowia lipolytica</i>	[68-71]
Poland	Brynza	<i>Citrobacter freundii</i> , <i>Lc. lactis</i> , <i>Lcb. casei</i>	[72]
	Bun	<i>Enterobacter aerogenes</i> , <i>Leu. mesenteroides</i> , <i>Ls. monocytogenes</i> , <i>Lvb. brevis</i>	
	Oscypek	Bacteria: <i>Citrobacter freundii</i> , <i>Clostridium butyricum</i> , <i>Enterobacter aerogenes</i> , <i>Esch. coli</i> , <i>L. crispatus</i> , <i>L. helveticus</i> , <i>Lc. garvieae</i> , <i>Lc. lactis</i> , <i>Lc. raffinolactis</i> , <i>Leu. citreum</i> , <i>Leu. lactis</i> , <i>Leu. mesenteroides</i> , <i>Leu. pseudomesenteroides</i> , <i>Lpb. paraplantarum</i> , <i>Lpb. plantarum</i> , <i>St. aureus</i> , <i>Str. parauberis</i> , <i>Str. salivarius</i> , <i>Str. thermophilus</i> , <i>Str. uberis</i> , <i>Str. vestibularis</i> Yeast or molds: <i>C. pararugosa</i> , <i>C. zeylanoides</i> , <i>Debaryomyces hansenii</i> , <i>Geotrichum silvicola</i> , <i>Kluyveromyces marxianus</i> , <i>Phialemonium</i> spp., <i>Saccharomyces</i> spp., <i>Tetragenococcus halophilus</i> , <i>Torulasporea</i> spp., <i>Yarrowia lipolytica</i>	[72-74]
Redikolka	<i>Citrobacter freundii</i> , <i>Clostridium tyrobutyricum</i> , <i>Enterobacter aerogenes</i> , <i>L. acidophilus</i> , <i>L. helveticus</i> , <i>Lc. lactis</i> , <i>Lcb. casei</i> , <i>Leu. mesenteroides</i> , <i>Ls. monocytogenes</i> , <i>Lmb. fermentum</i> , <i>Lvb. brevis</i> , <i>Propionibacterium jensenii</i> , <i>St. aureus</i>	[72]	
Ukraine	Brynza and bunz	<i>E. durans</i> , <i>E. faecium</i> , <i>Lc. garvieae</i> , <i>Lc. lactis</i> , <i>Lc. lactis</i> subsp. <i>lactis</i> , <i>Leu. mesenteroides</i> , <i>Lpb. plantarum</i>	[75-77]

A. – Acinetobacter; C. – Candida; E. – Enterococcus; L. – Lactobacillus; Lc. – Lactococcus; Lcb. – Lacticaseibacillus; Leu. – Leuconostoc; Llb. – Lentilactobacillus; Lmb. – Limosilactobacillus; Lo. – Loigolactobacillus; Lpb. – Lactiplantibacillus; Lvb. – Levilactobacillus; P. – Pediococcus; Str. – Streptococcus.

Slovenian brynza has a special microbiological diversity. Unlike Moldovan, Polish and Ukrainian samples of this cheese, it differs in a significant amount of yeast and mold fungi, which has been demonstrated by various microbiological methods in research [68-71]. Ukrainian authentic white brined cheeses, such as brynza and bunzu, show lower species diversity in their microbiota, but they contain *Enterococcus* species. Additionally, research [76] indicates the antagonistic activity of LAB strains isolated from authentic Ukrainian cheeses against foodborne pathogens like *Staphylococcus aureus*, *Listeria monocytogenes*, *Salmonella typhimurium*, and *Escherichia coli*, which can be the reason of their absence in the final product, distinguishing them from authentic cheeses of other countries.

In Western regions of Ukraine, cheese production like urda or vurda from by-products of other cheese production, like whey, is characteristic [79]. However, the typical microbiota of this cheese has not been studied.

Authors [80] examined 16 samples of sheep's cheese, including bryndza, butsu, and vurda, made on different mountain pastures in the Rahiv district and found that, microbiologically, all samples showed the presence of pathogenic microflora. *Staphylococcus aureus* was detected in most samples, while *Staphylococcus epidermis* in some of them. *Salmonella* was found in sample 2, *Enterobacter aerogenes* – in sample 16, and molds – in sample 4. It is essential to note that these results cannot be generalized to all producers in the Carpathian region, but they emphasize the need for work at the producer level to strike a balance between preserving traditional production methods and ensuring product quality and safety, especially in the context of European integration processes.

Challenges in the Production of Authentic Cheeses. Production of authentic cheeses, like any other type of cheese, is a complex process. However, due to the specific characteristics of authentic cheeses from various countries, production is complicated not only by the requirements for raw materials but also by the rich microbiological diversity of the final product. Additionally, there are certain technological features that can be utilized only in small-scale or home-based cheese production [26,29].

One of the most common categories of cheeses considered authentic are rennet-curdled and white brined cheeses. The general stages of production for cheeses of this type are presented in Figure 3.

While standard technological schemes for producing bryndza, feta, and bunza have been developed, the main challenge lies in creating a product with the authentic primary taste, aroma, and flavor. To improve product quality and produce various authentic cheeses, new starter cultures are being developed. A significant approach to creating starter cultures is

selection of microorganisms typical for the authentic product [81]. For example, in study [82], organoleptic, physicochemical, and microbiological parameters of bryndza made using the "Enteroplan" preparation, which contains the following starter cultures: *Lc. lactis*, *Lpb. plantarum*, and *E. durans*, characteristic of authentic Ukrainian bryndza, were investigated. Compared to the control sample, the experimental bryndza showed better organoleptic properties and a higher colony-forming units per gram of product. Research is also conducted on the use of various salting technological regimes [83], salts to extend the shelf life of cheese [84], rennet enzymes in the final product [85], and so on. The possibility of changing the bryndza recipe [86] and improving the manufacturing technology by adding a bio-protective culture is being studied [87]. Special attention is given to developing the technology of making urda, as presented in works [59,88].

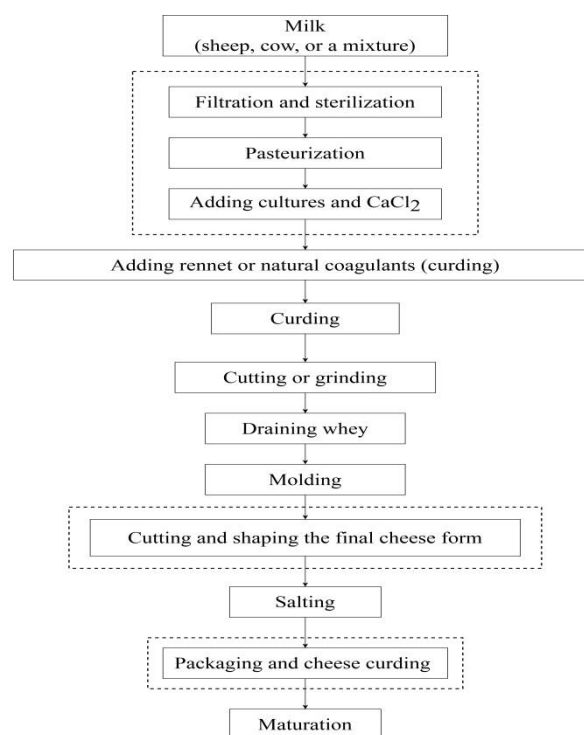


Fig. 3. General scheme of cheese production (highlighted stages are omitted in small-scale or manual production).

As for cheeses with complex microbiota (Polish oscypek, Slovenian bryndza), researchers pay more attention to the sensory characteristics of authentic products made from different types of milk or their substitutes, as demonstrated for Slovenian parnica [58], Slovenian bryndza [89], and Polish bunza [90]. In work [91], the aromatic compounds typical for Polish oscypek, which give the cheese a unique taste and aroma, were analyzed.

It can be stated that further research into the technological aspects of producing various authentic cheeses, such as urda and bunza, is necessary. Today, the existing bryndza production technology is actively used. However, to give the cheese a more authentic taste, the creation of new starter cultures, the use of different types of milk (sheep, goat, or blends), and the development of craft production are possible. These steps could draw attention to the product and increase demand for authentic cheese.

Conclusion

Authentic cheeses are a unique cultural heritage of many regions and countries around the world. The majority of authentic cheeses worldwide are concentrated in Europe, which is linked to the historical origins and development of cheese-making in the region. To protect intellectual property and cultural traditions, there exist specific protected designations of origin today, the most important of which are PGI and PDO. A significant number of authentic cheeses from European Union countries have these designations, with Italy and France being the leaders in terms of the number of registered authentic cheeses. However, many other countries have their own distinctive authentic cheeses, such as Poland, Slovakia, Romania, Greece, Moldova, Ukraine, Turkey, and others. The most typical cheeses for these countries are rennet-curd

and white brined cheeses, such as bryndza, bunz, oscypek, and others.

Authentic cheeses have some unique features, the main ones being the raw materials used to make the cheese, the cheese-making process, and the microbiota of the final product. It is widely recognized that the primary factor influencing the final product is the raw material, namely milk. For certain cheeses, like Slovenian bryndza, there are variations in the microbiological composition depending on the type of milk used. The microbiota of many authentic cheeses is complex and can vary significantly depending on the region. However, a common feature of all authentic cheeses is the presence of various lactic acid bacteria and sometimes specific foodborne pathogens, which are inhibited by particular dominant lactic acid bacteria. This applies to the production of Carpathian sheep's milk bryndza and Carpathian cow's milk bryndza.

Today, technologies have been developed for the production of certain authentic cheeses, including bryndza. However, fully reproducing the authentic taste and aroma of these products is complicated due to the challenges of replicating the microbiota and using processed milk. To enhance the organoleptic properties of these cheeses, various studies focusing on creating starter cultures and improving the recipes of authentic cheeses are conducted.

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АВТЕНТИЧНІ СИРИ: МІКРОБІОЛОГІЯ, ЗАКВАСКИ ТА ТЕХНОЛОГІЧНІ АСПЕКТИ ВИРОБНИЦТВА

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Анотація. Робота присвячена різновидам, мікробіологічним особливостям та технологічними особливостями виробництва окремих видів автентичних сирів. Метою роботи було визначити біотехнологічні особливості виробництва автентичних сирів, проаналізувати різновиди таких сирів та їх мікробіоту, визначити технологічні різновиди виробництва сирів. Використовувались монографічний, конструктивний методи, а також методи причинно-наслідкового аналізу і логічного узагальнення. Сир – найпопулярніший у світі харчовий продукт, існує 5000 сортів сиру. Хоча найбільш популярними та поширеними сирами є стандартні та вироблені на багатотоннажних виробництвах, традиційні сири також користуються популярністю завдяки своїм унікальним органолептичним властивостям. На унікальні характеристики традиційних сирів впливає багато факторів, основними з яких є якість молока, його мікробіологічний і хімічний склад та технологічні прийоми, що використовуються при виготовленні сиру. Для всіх традиційних сирів характерна присутність молочнокислих бактерій, однак використання необробленого молока іноді зумовлює наявність харчових патогенів у готовому продукті. Певні сири мають досить складну мікробіоту, що ускладнює їх виробництво та створення заквашувальних культур. Однак для багатьох сирів, особливо таких як бринза, сьогодні створені технологічні підходи для виробництва, а більшість досліджень направлені на досягнення автентичного смаку і покращення органолептичних властивостей готового продукту. Аналіз кількісного та якісного складу заквашувальної мікробіоти та технологічних особливостей різних видів традиційних сирів дає змогу визначитися зі складом нових заквашувальних композицій, які притаманні для того чи іншого продукту та підібрати шляхи підвищення ефективності виробництва таких сирів.

Ключові слова: традиційні сири, виробництво, мікробіота, біотехнологія, молочнокислі бактерії, закваска.