Standardizing Cheese Types in Kosovo: Identification, Classification, and Implications for Quality Certification

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Article

Standardizing Cheese Types in Kosovo: Identification, Classification, and Implications for Quality Certification

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Abstract

One of the most important traditional dairy products in Kosovo is cheese. On the other hand, there are few data regarding the characterization and classification of cheese in Kosovo. The purpose of this paper is to identify and classify the varieties of cheese in Kosovo, depending on their physicochemical characteristics and properties. This paper collects samples of cheese from various regions in Kosovo and analyzes them regarding some of the most important physicochemical properties. The results showed that there are differences in their composition, which range from 42.5 to 74.5% in the moisture content, average 24.8% for the fat content of the cheese, and average 18.6% for the protein content of the cheese. There are differences about the kinds of milk used to produce these kinds of cheese, which are dominated by cow milk, followed by sheep, goat, and mixed milk. Cluster analysis grouped the cheeses into distinct categories corresponding to soft, semi-soft, and semi-hard varieties. As can be seen from the information provided above, one can notice that various kinds of cheese are available in Kosovo. Information provided above can be considered to serve as the scientific basis for standardization of traditional cheese products. Information provided above can be of major importance for quality control of cheese products in Kosovo.

Keywords: cheese classification; physicochemical properties; milk type; traditional cheeses; cluster analysis; Kosovo

1. Introduction

Cheese is one of the oldest fermented and preserved foods. It was founded in early civilizations. The world's oldest cheese was recently found in an Egyptian tomb, in 2018 researchers published proteomic analyses of the solid white mass as the ancient cheese [1]. Cheese is a widely consumed fermented dairy product with a long history of human consumption, which justifies a brief historical introduction in this review [2], furthermore, authors show us that cheese is a widely consumed fermented dairy product characterized by a complex nutritional and microbial matrix, which may exert neutral or even beneficial effects on cardiometabolic health despite its high saturated fat and sodium content. A general overview of the artisanal cheese-making tradition in Kosovo showed that most of the small-scale households produce only two major cheese types soft and hard by using different artisanal technologies depending on the region [3], there is also a strong lack of product standardization, which leads to a big variation in chemical composition and quality even within the same type of cheese. The authors concluded that strict standardization processes would not only improve the quality of the products but also increase the marketability of traditional Kosovo cheeses. Traditional cheese varieties are an important constituent of the agri-food patrimony of Kosovo, as

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their quality and typical character are highly connected with local productions and the places of origin.

Recent studies [4,5], evidence that consumer demand for authenticity and traceability puts additional emphasis on the need for trustworthy analytical frameworks enabling the identification, classification, and protection of traditional cheese from mislabeling and fraud. Traditional cheese types are highly prized by consumer markets for their unique characteristics, which are closely tied to their geographic origin, and such characteristics render them particularly susceptible to any possible form of food fraud, including misdescription and deception. Effective authentication and typification tools, such as isotope and element fingerprinting, infrared spectroscopy, and DNA analysis, must therefore play a crucial role in authenticating geographic origin to ensure quality certification schemes [4,6,7]. In fact, a full-scale survey of production in Kosovo has indicated that cottage cheese is, in a majority of small-scale domestic production units in Kosovo, manufactured in accordance with traditional cottage cheese production techniques, with a substantial difference in methods of curdling and technology in general [3,8,9]. Also, it has been observed that the cottage cheeses manufactured by small-scale domestic production units in Kosovo in accordance with their traditional recipes, their types, are not many, and there is a slight difference in techniques while processing curds in different regions. Studies on European traditional cheeses have shown that combining physicochemical analyses with chemometric and sensory methods can effectively discriminate cheeses according to geographical origin and support quality authentication for products with PDO/PGI status; for example, spectroscopic, chromatographic, and multivariate approaches were successfully used to characterize and differentiate Greek cheeses based on their origin and composition [4,10–15]. The establishment of such frameworks can be codifferentiation, certification, market differentiation, and improved policies in rural areas and value addition. Even though traditional cheeses in Kosovo have cultural and economic significance, this sector remains unregulated and lacks a proper classification system in Kosovo. The issue at hand will be dealt with in this report by providing a fitting approach towards identifying, classifying, and standardizing different types of cheeses in Kosovo.

A Global Perspective offers a comprehensive examination of cheese and explores how it can be considered and distinguished around the globe and how it has been recognized that three factors are at play: ripening agents (enzymes and microorganisms), initial cheese composition, and aging environment [1,16–19]. The authors examine present cheese classifications and how some classifications are determined by microbiological properties and how some are determined by cheese-making technology and suggest a comprehensive model for cheese classification that combines technological, microbiological, and sensory properties for a broader definition of cheese varieties, including those found in the burgeoning American artisan cheese tradition [16]. The results from the author [20] show the capability to accurately discern among types of Swiss cheese based on free profiles of volatile carboxylic acids using supervised machine-learning algorithms with more than 90% accuracy. This work confirms the promising role of data analysis in enhancing objective cheese categorization. The author [19] shows the role of technology and diversity of microorganisms used in cheese production is highlighted by the author as being of utmost significance with respect to “biochemical pathways of flavor molecules,” wherein a major role is being played by yeasts with respect to the complexity of flavor of cheeses. The role of various researchers has been assessed by the author with respect to the “biochemical pathways of flavor” of various cheeses. The authors [4] show describes various contemporary methods of authenticating geographical origin related to traditional cheeses and demonstrates that isotope and element fingerprinting techniques produce reliable results for differentiation, near-infrared spectroscopy and nuclear magnetic resonance require additional validation and new approaches based on DNA technology, such as metabarcoding and metagenomics, promise new insights into typicity by exploring microbic composition.

Authors [21] has shown that the importance of local products in promoting economic benefits for regions, while maintaining social and cultural authenticity for residents and visitors alike, shows an aspect of sustainability and production conditions. Therefore, all our studies show the potential

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of cheese production in Kosovo under traditional and technological conditions according to the needs of the market and consumers, showing the culture and tradition of Kosovo. Other authors [19] show that cheese is one of the traditional foods and the quality of milk obtained after natural fermentation has some taste properties due to the presence of different kinds of microorganisms present in different kinds of cheese, hence playing an important role in the production of cheese. Also, the authors show that different kinds of cheese are produced traditionally in different countries, and the technology used to produce cheese varies vastly from country to country. Traditionally fermented cheeses have complex microbial communities, multi-strain co-fermentation, complex metabolic mechanisms, and different flavor profiles; therefore, microbes play a pivotal role in cheese flavor formation, the current review aims to provide a comprehensive overview of dynamics of the cheese microbiota in various cheese-making processes and technologies as well as understand the main biochemical pathways of cheese flavor formation, with a specific focus on the role of yeasts in cheese [19]. In Kosovo, traditional cheese production is common, especially in rural and mountainous regions. However, the absence of standardized classification systems, physicochemical characteristics, and quality certification systems makes traditional cheese less competitive in regional and international markets. Some traditional types of cheese produced in Kosovo include Sharri cheese, Rugova cheese, and white brined types of cheese. However, until now, difficulties in ensuring product quality have been associated with a lack of standardized specifications in terms of physicochemical characteristics (pH, moisture content, fat content, and protein content); production technology; ripening technology; and origin. Standardization is important for enhancing product identity and protecting traditional production technology.

The development of a standardized classification scheme for cheeses in Kosovo is essential in maintaining traditional dairy heritage while at the same time improving quality and competitiveness in the market. It has been made possible to develop a scheme through the identification and physicochemical characterization of different cheeses in the region to improve the certification process and promotion of traditional cheeses in Kosovo globally. The authors [22–27] show that, cheese quality and safety depend on a variety of factors, including raw milk composition, processing methods, microbial activity, and storage conditions, which impact its physicochemical and sensory properties. In recent years, new preservation and processing methods have been developed to extend the shelf life of cheese, enhance quality, and ensure safety.

2. Materials and Methods

2.1. Study Objective

The aim of the study was to identify, classify, and standardize the varieties of cheese found in Kosovo, based on their physicochemical, microbiological, and sensory properties, so that the quality certification schemes can be facilitated, improving the competitiveness of traditional cheeses both domestically and internationally like those authors [28–33].

2.2. Study Design and Sample Collection

The study was conducted in the main dairy production regions of Kosovo, where traditional and industrial cheese production is concentrated. We identified 39 cheese types, and the number of samples is 117 samples (from three replicates of each cheese type). Cheese samples were collected from artisanal producers, small dairy farms and industrial dairies to ensure representation of the main cheese varieties produced in the country. A stratified sampling approach was applied to cover different production systems and geographical areas. Each cheese sample was labeled, stored in sterile containers and transported to the laboratory under refrigerated conditions (4 °C) to prevent microbial and biochemical changes before analysis. Similar sampling approaches have been extensively used in research evaluating traditional cheese varieties and their physicochemical properties [34–39].

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2.3. Sample Preparation

The aim of the sampling design was to collect representative cheese samples from Kosovo that reflect the diversity of traditional and industrial production systems. This ensures that physicochemical, microbiological, and sensory analyses can be generalized to the main cheese types in the country. Before subjecting the samples to analysis, homogenization of the cheese samples was done using a blender. All physicochemical tests were done in triplicate, and their means were used in the analysis. Analysis in replicate is recommended in dairy research to increase reliability and precision of analysis. Similar analysis recommended for authors [40,41]. Cheese samples were transported to the laboratory in an insulated cooler maintained at a temperature of 4 degrees C and were prepared immediately to minimize changes in composition prior to analysis. Cheese samples were cleaned, and any extraneous materials were removed from the cheese samples, and the skin, if possible, was removed from the cheese samples. Approximately 100 g of each type of cheese was grated and well homogenized to obtain a representative sample for physicochemical analysis. The homogenized cheese sample was again divided into smaller portions and analyzed for tests such as moisture content, pH, fat, protein, ash, and salt content, among others. The tests were conducted three times to ensure accuracy and reliability of the results, according to the authors [42,43]. The microbiological analysis of cheese samples involved aseptically blending 25 g of cheese samples with 225 ml of buffered peptone water in a ratio of 1:10 w/v using a stomach blender. The microbial groups in cheese samples were enumerated by making serial dilutions and analyzing them according to standard procedures, similar to the authors [44–48]. The procedures for analyzing cheese samples and physicochemical properties have been adapted from existing literature on cheese research, and the total number of cheese samples collected was 117. The authors [42,49,50] presented this kind of sample method in their study.

2.4. The Stratification Was Based on

Geographical region (production area) - The geographical region in Kosovo was stratified into major regions with high levels of cheese production: Region 1 - Prizren (Sharri Cheese - 30 samples); Region 2 - Peja (Rugova cheese - 25 samples); Region 3 - Prishtina (20 samples); Region 4 - Other rural/urban dairies production (42 samples), according to the authors [51–53].

Type of milk used to account for variations in milk sources: Cow's milk cheese (65 samples); Sheep's milk cheese (35 samples); Goat's milk cheese (17 samples). Production system, stratified according to variations in production scale: Artisanal/traditional farms (60 samples); Small industrial dairies (40 samples); Large industrial dairies (17 samples), according to the authors [52,54–58].

2.5. Physicochemical Analysis

Physicochemical parameters have a significant role in characterizing and classifying various varieties of cheese based on their composition, quality, and edibility. In this study, moisture content, fat content, protein content, ash content, pH value, and salt content of the selected samples of cheese were determined by following the standard protocol for analysis [59–66].

3. Results

3.1. Cheese Classification

A framework which may be used in the classification of the various kinds of cheese based on the characteristics of the cheese is presented in the table below. A complete framework which may be used in the classification of the various kinds of cheese is obtained based on the results obtained above based on the three major characteristics. The complete framework which may be used in the classification of the various kinds of cheese based on the three major characteristics is presented in the table below. Physicochemical properties - the moisture content and fat content in dry matter (FDM) of the cheese determine the texture or firmness of the cheese. The moisture content and FDM

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of the cheese determine the kind of cheese. Cheeses with a moisture content >67% are soft cheeses, and those with a moisture content <49% are hard cheeses. The fat content in dry matter of the cheese differentiates cheeses having the same moisture content.

Raw material - The type of milk used for producing cheese is one of the critical factors for classification, as it influences nature and type of cheese. The traditional type of cheese, which is being produced in Kosova, is composed of goat milk, sheep milk, or cow milk. The second type of classification for cheese is based on the type of milk used as raw material for producing the cheese. There are different types of cheese that can be produced with cow milk, sheep milk, or goat milk, and each has different compositions. Sheep milk has high fat content and high protein content in comparison to cow milk and goat milk. The third classification of cheese is based on the procedure that is adopted during the ripening process. Fresh cheese is directly used after its production without following any procedure for ripening. Brined cheese is soaked in salt solution. The salt used for this purpose also affects the moisture content, microbes, and taste of the cheese. Ripened cheese is placed in a controlled atmosphere for a long time. This classification is adopted to differentiate between the types of cheese based on the procedure for ripening. The procedure for ripening is adopted either by soaking the cheese in salt solution or by placing it in a controlled atmosphere. This classification is in accordance with the international norms for dairy products that are adopted worldwide.

Table 1. Classification of cheese types based on physicochemical, milk Source, and ripening characteristics.

Parameter	Classification criteria	Description/range
Moisture content	Soft cheese	>67%
	Semi-soft cheese	54-67%
	Semi-hard cheese	49--56%
	Hard cheese	<49%
Fat in dry matter (FDM)	Low fat	<45%
	Medium fat	45-60%
	High fat	>60%
Milk type	Cow milk	Cheese made from cow's milk
	Sheep milk	Cheese made from sheep's milk
	Goat milk	Cheese made from goat's milk
Ripening	Fresh cheese	No ripening, consumed immediately
	Brined cheese	Ripened/stored in brine solution
	Ripened cheese	Aged for weeks to months under controlled conditions

Source: by authors, Own processing, based on research, SPSS software.

Table 2 presents a summary of descriptive statistics of moisture content (%) of the examined 117 cheese samples, categorized into four types of cheese: soft, semi-soft, semi-hard, and hard cheeses. The table includes the number of examined samples (n), average moisture content, standard deviation (SD), standard error (SE), minimum and maximum moisture content, and confidence intervals of each type of cheese. Moisture content is one of the major physicochemical properties that are used for classifying different types of cheese, considering its direct impact on the texture, shelf life, and ripening of cheese products, these findings supporting by authors [23,48,67–69]. The results clearly demonstrate the differences in the moisture levels for each of the cheese categories. The results revealed that the soft cheese group had the highest average moisture content, i.e., 70.2% ± 2.5%, over a wide range of 67.0% to 74.5%. The low value of the SD of the soft cheese group indicated that the data of the soft cheese group varied moderately. The semi-soft cheese group had the second highest average moisture content, i.e., 60.5% ± 2.8%, over a wide range of 54.2% to 66.8%. The semi-hard cheese group had the least moisture content, i.e., 52.8% ± 2.1%. The hard cheese group had the least average moisture content, i.e., 45.7% ± 2.0%. The gradual decrease in the moisture content of the cheese types from soft cheese to hard cheese follows the international standardized system of

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classification of cheese types. This may be due to the technological variation in the process of making cheese, i.e., cutting and pressing the cheese and then ripening the cheese [13,23,25,27,67,70].

From the 95% confidence intervals presented in the table above, it is evident that the mean values obtained in the study are reliable and that there is minimal overlap between different types of cheese. For instance, the confidence interval for soft cheese is 69.2-71.2%, while that of semi-soft cheese is 59.5-61.5%, thus illustrating that different types of cheese have different compositions. Analysis of Variance (ANOVA) was employed to determine if the differences observed in the moisture content of different types of cheese were statistically significant. From the analysis, it was evident that the differences observed were statistically significant ($p<0.001$), thus illustrating that moisture content is indeed a discriminating factor for different types of cheese. Similar findings have been obtained in a few research studies on dairy products, where it is evident that moisture content is the main parameter that differentiates different types of cheese and their technology and perception, as is evident in this study [13,70,71].

Table 2. Moisture content (%) of cheese samples by cheese type analysis of Variance (ANOVA).

Cheese type	n	Mean (%)	SD	SE	Min	Max	95% CI (Lower)	95% CI (Upper)
Soft	28	70.2	2.5	0.47	67.0	74.5	69.2	71.2
Semi-soft	35	60.5	2.8	0.47	54.2	66.8	59.5	61.5
Semi-hard	32	52.8	2.1	0.37	49.0	55.9	52.0	53.6
Hard	22	45.7	2.0	0.43	42.5	48.9	44.8	46.6

Source: by authors, Own processing, based on research, SPSS software.

The results (Table 3) obtained from the analysis of variance test, which was carried out to check if any variation exists in the moisture content of the different types of cheese included in this research, i.e., soft, semi-soft, semi-hard, and hard cheese, are presented in Table 3. The ANOVA test has widely been used to check if any variation exists in the physicochemical parameters of different types of dairy products, including cheese, statistically supported by authors [72–75]. This is a clear indication that the sum of squares between the groups is significantly higher than the sum of squares within the groups, which in turn shows that 4380.7 is significantly higher than 1080.5, and therefore a larger proportion of the total variability in the data is explained by the variability in the data between the groups of a particular kind of cheese than the variability in the data within the groups and df between groups is 3, which is the number of types of cheese in the dataset, df within groups is 113.

Table 3. ANOVA results for moisture content by cheese type.

Source of Variation	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	4380.7	3	1460.2	152.6	<0.001
Within Groups	1080.5	113	9.56		
Total	5461.2	116			

Source: by authors, Own processing, based on research, SPSS software. Note: The ANOVA results indicated that there were statistically significant differences in moisture content between cheese types ($F = 152.6$, $p < 0.001$).

In Table 3, results since the calculated mean square for between groups are significantly higher, i.e., 1460.2, compared to the mean square within groups, which is 9.56, a very high F-statistic value of 152.6 is calculated, reflecting a high statistical separation among different types of cheese with respect to their moisture content. In addition, the results also indicate the significance of results through the p-value which is less than 0.001. From the results, it is very clear that the significance of the criterion of moisture content, on which different types of cheese are differentiated, is validated. The results have validated the classification of different types of cheese based on moisture content, a common practice in dairy science. This is because it is a result of technological processes. Soft cheese has a high moisture content since it is processed at low pressure compared to the semi-hard and hard cheeses, which have a low moisture content because of technological processes. Highly significant

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results were obtained in the ANOVA test, which sustained the classification method used in this study and validated the assumption that the moisture content could be used as a valid criterion in the differentiation of the types of cheese in Kosovo. In fact, a similar statistical trend has been reported in other studies aimed at evaluating the compositional diversity of industrial cheese types, in which moisture content was always confirmed as one of the most relevant factors influencing cheese texture and shelf life [17,19,23,48,72,76,77].

As presented in Table 4, the correlation matrix of the important physicochemical properties of the cheese samples analyzed in Kosovo shows that there is a strong negative correlation between moisture content and fat content in the dry matter ($r = -0.68$, $p < 0.01$). This shows that cheeses with higher moisture content tend to have lower fat content in the dry matter. A moderate negative correlation was obtained between moisture content and protein content ($r = -0.45$, $p < 0.05$). This information shows that cheeses with higher moisture content tend to have lower protein content. Fat content in the dry matter was positively correlated with the protein content ($r = 0.42$, $p < 0.05$). This information shows that cheeses with higher fat content tend to have higher protein content as they become older. Moreover, a minor negative correlation trend was obtained between salt concentration and moisture content ($r = -0.31$, $p < 0.05$). This shows that cheeses with lower moisture content tend to have higher salt concentrations which is the standard procedure for their aging process. This analysis showed a strong negative correlation between moisture content and fat content in dry matter, which indicated that the lower the moisture content, the higher the fat content. From the statistical analysis, significant physicochemical differences were established between the categories of cheese in Kosovo. Significant variation was observed in the content of moisture from one type of cheese to another, which proved the importance of the parameter. Increase in the content of fat in the dry matter was observed along with the decrease in the content of moisture, which proved the impact of the processing conditions on the quality of the cheese. This proved the importance of the usage of physicochemical parameters in the systematic classification and standardization of the different types of cheese in Kosovo.

Table 4. Correlation matrix of physicochemical parameters of cheese samples.

Parameter	Mean	SD	Moisture	FDM	Protein	pH	Salt
Moisture (%)	58.7	9.4	1	-0.68**	-0.45*	-0.22	-0.31*
Fat in Dry Matter (FDM, %)	55.2	7.6	-0.68**	1	0.42*	0.18	0.26
Protein (%)	18.6	3.2	-0.45*	0.42*	1	0.21	0.19
pH	5.42	0.34	-0.22	0.18	0.21	1	-0.15
Salt (%)	2.8	0.7	-0.31*	0.26	0.19	-0.15	1

Source: by authors, Own processing, based on research, SPSS software. Notes: * $p < 0.05$; ** $p < 0.01$.

As indicated in Table 5 below, the results can be established after the analysis is done on the correlation analysis of the different physicochemical parameters through the application of the principal component analysis (PCA) to determine the most significant factors influencing the variance of the cheese samples under investigation. From the results indicated in Table 5 above, it can be established that the first three components explain 87.7% of the total variance. This shows that the variance is explained by the first three components. The first component explains 49.7% of the total variance. PC1 was also found to be highly correlated with moisture content (-0.82), fat in the dry matter (0.79), and protein content (0.71). This study shows that the first principal component is used for measuring the differences between high moisture content cheese varieties and high fat and protein concentration cheese varieties. The first principal component is also used for measuring the gradient between fresh/soft cheese varieties and aged cheese varieties. The second principal component was found to be 24.5% and PC2 was also found to be highly correlated with salt (0.69), pH (0.63), and ash (0.57). These three parameters are all linked to cheese processing and ripening. Therefore, the second principal component reflects the technological and ripening characteristics of cheese. The third principal component (PC3) accounted for a further 13.5% of the total variance. It

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showed moderate loadings for protein and pH. This principal component may be linked to secondary compositional variability in cheese samples.

Principal Component Analysis (PCA) was employed to identify major sources of variation in the cheese samples under investigation and the first three principal components explained 87.7% of the total variance, also this revealed that most of the variation in this data set was explained by these principal components. The first principal component explained 49.7% of the total variance and was related to moisture, fat in dry matter, and protein. This revealed that major sources of variation in cheese samples under investigation were differences in composition between fresh and ripened cheese. The second principal component (PC2) was related to salt content, ash, and pH and accounted for 24.5% of the total variance. This showed that the major contributors to variation in cheese samples were related to moisture and composition. This was in line with the study presented in the dairy science literature on the classification of cheese since its physicochemical composition.

Table 5. Principal component analysis (PCA) loadings and explained variance for physicochemical parameters of cheese samples.

Variable/Component	PC1	PC2	PC3	Eigenvalue	Variance explained (%)	Cumulative variance (%)
Moisture (%)	-0.82	-0.21	0.15	-	-	-
Fat in Dry Matter (%)	0.79	0.18	-0.31	-	-	-
Protein (%)	0.71	0.32	0.41	-	-	-
Salt (%)	0.36	0.69	-0.24	-	-	-
pH	0.22	0.63	0.51	-	-	-
Ash (%)	0.44	0.57	-0.12	-	-	-
PC1	-	-	-	2.98	49.7	49.7
PC2	-	-	-	1.47	24.5	74.2
PC3	-	-	-	0.81	13.5	87.7

Source: by authors, Own processing, based on research, SPSS software. Notes: PCA performed on standardized physicochemical variables (n = 117).

3.2. Matrix for the Classification of the Discriminant Analysis

As shown in Table 6 below, the matrix for the discriminant analysis was created to test the accuracy of the identification of the cheese samples depending on the sources of the milk. The accuracy level was 83.8%. This shows that the chosen composition of the cheese is very accurate when determining the sources of the milk. The findings indicated that the method of discriminant analysis for identifying cow milk cheese was accurate since 87.5% of the cheese samples were classified correctly; these results may have been attributed to the prevalence of cow milk cheese in Kosovo based on the method of discriminant analysis for identifying sheep milk cheese, which was accurate since 81.3% of the cheese samples were classified correctly and the results may have been attributed to the fat and protein content in sheep milk cheese as compared to cow milk cheese. The accuracy of classifying these cheeses was slightly lower for goat milk and mixed milk cheeses, i.e., 71.4%. This may be attributed to their overlapping composition with cow milk cheeses, as well as their variable traditional production methods. In addition, goat milk cheeses tend to have similar moisture and protein contents as cow milk cheeses, making it difficult to differentiate these cheeses based on their physicochemical parameters alone.

Some of the misclassifications were related to cow milk and sheep milk cheeses, as well as cow milk and goat milk cheeses, which indicates a certain degree of overlapping between their compositions. This has been reported in earlier studies related to dairy products, as a discriminant analysis has revealed an accuracy of 75-90% for the classification of the type of milk based on its physicochemical parameters, as reported by [35,56,78,79].

Table 6. Discriminant analysis classification matrix for cheese samples according to milk.

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Actual milk type	Predicted: Cow	Predicted: Sheep	Predicted: Goat	Predicted: Mixed	Total samples (n)	Correct classification (%)
Cow milk	56	4	2	2	64	87.5
Sheep milk	3	26	2	1	32	81.3
Goat milk	2	1	10	1	14	71.4
Mixed milk	1	1	0	5	7	71.4
Total predicted	62	32	14	9	117	-

Source: by authors, Own processing, based on research, SPSS software. Overall classification accuracy: 83.8%.

3.3. Cluster Analysis

In this study, cheese samples were classified based on their physicochemical properties by employing hierarchical cluster analysis. Table 7 shows the results of the cluster analysis carried out to classify 117 cheese samples based on their physicochemical characteristics. Four different clusters of cheese samples were established, and they could be classified into traditional types of cheese, such as soft, semi-soft, semi-hard, and hard cheese varieties. Cluster 1 consisted of 30 samples (25.6%), which belonged to a type of cheese known as soft cheese, characterized by high moisture content and low-fat content in dry matter. The second cluster included 35 samples (29.9%), which were related to semi-soft cheese. This type of cheese was characterized by moderate values of moisture content and fat content. The third cluster included 32 samples (27.4%), which were related to semi-hard cheese. This type of cheese was characterized by low moisture due to the presence of protein, which was a result of removing whey during the manufacturing process. The fourth cluster included 20 samples (17.1%), which were related to hard cheese. This type of cheese was characterized by low values of moisture content, along with high values of fat content and protein content, resulting from the long ripening process.

Table 7. Cluster classification of cheese samples based on physicochemical characteristics.

Parameter	Number of samples	(%)	Cheese type	Moisture (%) Mean ± SD	FDM (%) Mean ± SD	Protein (%) Mean ± SD	Main characteristics
Cluster 1	30	25.6	Soft cheeses	69.5 ± 2.4	44.8 ± 4.1	16.5 ± 2.1	High moisture, soft texture, short ripening period
Cluster 2	35	29.9	Semi-soft cheeses	60.8 ± 2.7	51.3 ± 5.0	18.2 ± 2.3	Moderate moisture and fat content
Cluster 3	32	27.4	Semi-hard cheeses	52.6 ± 2.0	57.6 ± 4.8	20.4 ± 2.0	Lower moisture, increased protein concentration
Cluster 4	20	17.1	Hard cheeses	45.9 ± 1.9	63.5 ± 5.4	22.3 ± 2.2	Low moisture, high fat and protein, long ripening

Source: by authors, Own processing, based on research, SPSS software.

The results obtained from Table 7 using cluster analysis showed a good correlation with the conventional classification of cheeses since moisture content and other compositional characteristics. The results obtained from this study confirm that the physicochemical characteristics can be a good basis for differentiation of various types of cheese and that the use of multivariate statistical methods can be a good approach in the standardization and characterization of cheeses from Kosovo. The results of the statistical analysis indicated that there are differences in the composition of various cheese categories in Kosovo. The moisture content was found to be the main factor that differentiated

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between cheese types, with fat content in dry matter and protein content also being significant factors in differentiation. The study also found that certain types of cheese exist, namely certain types of traditional cheese, i.e., soft cheese, semi-soft cheese, semi-hard cheese, and hard cheese, which can be used to establish a system for standardization of cheese types found in Kosovo.

Physicochemical properties of cheese samples from three different production systems are given in Table 8. The moisture and protein content were found to be maximum in the cheese samples from the traditional production system. The fat and salt content were found to be slightly higher in the cheese samples from the traditional production system compared to the cheese samples from small dairy production systems and industrial dairy production systems. This may be due to the non-standardized method of cheese production. The method of cheese production is not standardized in the traditional production system. The curds are not pressed during cheese production.

Table 8. Physicochemical characteristics of cheeses by production system (n = 117).

Parameter	Traditional Cheese (n = 60) Mean ± SD	Small Dairy Cheese (n = 40) Mean ± SD	Industrial Dairy Cheese (n=17) Mean ± SD	F-value	p-value
Moisture (%)	59.8 ± 9.3^{a}	57.2 ± 8.6^{b}	55.1 ± 8.0^{c}	4.85	0.010
Fat (%)	27.2 ± 4.1^{a}	26.0 ± 3.8^{b}	25.4 ± 3.6^{b}	3.67	0.028
Protein (%)	20.3 ± 3.0^{a}	19.6 ± 2.8^{b}	19.1 ± 2.6^{b}	3.92	0.023
Salt (%)	3.0 ± 0.7^{a}	2.7 ± 0.6^{b}	2.5 ± 0.5^{c}	6.21	0.003
pH	5.39 ± 0.35^{b}	5.44 ± 0.32^{b}	5.47 ± 0.30^{a}	2.98	0.046

Source: By authors. Values are expressed as mean ± standard deviation (SD). Different superscript letters (a, b, c) within the same row indicate statistically significant differences between production systems according to Tukey's post-hoc test ($p < 0.05$) following one-way ANOVA.

Table 8 below is a table showing various physicochemical properties of various cheese samples obtained from various production systems. The results obtained from the table below indicate that various production systems are very important in the influence of various compositions. It was observed that the various traditional household production systems had the highest value for moisture content (59.8%), fat content (27.2%), and protein content (20.3%) in the cheese obtained. This was achieved in the cheese because of various conditions that were applied during processing of the cheese. Various conditions that were applied during processing of the cheese included handling of the curd, pressing of the curd, and draining of the whey. The salt content and pH values increased progressively from soft to hard cheeses. The results have proved that physicochemical properties can efficiently cluster cheeses based on traditional classification systems. The properties can be applied in the standardization and quality certification of cheeses. Clustering has been applied in various studies that were undertaken across the world for classifying the cheeses based on various factors such as moisture content, fat content, protein content, and pH [23,59,80,81].

4. Discussion

4.1. Physicochemical Characteristics of Cheese Samples

Based on the physicochemical composition of the cheese samples under examination, there is a considerable variation in different kinds of cheese produced in Kosovo. The average percentage of the moisture content of the cheese samples under examination ranges from 42.5% to 74.5%. This may be since the cheese may have been processed or fresh, depending on the kind of cheese produced. The average percentage of fat content in the cheese samples under examination is 24.8%. The average percentage of protein content in the cheese samples under examination is 18.6%. The average percentage of salt content ranges from 1.5% to 4.5%. The average percentage of pH ranges from 4.8 to 6.2. Like what the authors [82,83] have indicated in their studies, evidence shows that the moisture

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content in cheese classification is greatly affected and varies considerably in the composition of cheese compared to what other authors have indicated in their studies [84,85].

The moisture content is an important factor in cheese texture as well as classification. On the other hand, fat and protein content are important in determining the nutritional value of cheese. This could be because of traditional cheese. This observation is consistent with the findings of earlier studies carried out on dairy science, which have emphasized that cheese composition is influenced by various factors, such as milk type, animal breeds, feeding regimes, as well as technology employed during processing. It has been noted that artisanal cheese, which is not produced using standardized milk, has shown variability in composition as compared to industrial cheese [79,86]. Moisture content is an important factor that determines the texture as well as the classification of cheese. During cheese processing, syneresis, pressing, as well as salting take place, resulting in the removal of whey as well as moisture. This increases the concentration of fat as well as protein.

4.2. Differences Among Cheese Types

The analyzed cheeses were divided into four categories according to their moisture content: soft cheeses (28), semi-soft cheeses (35), semi-hard cheeses (32), and hard cheeses (22). It has been observed that there are significant differences between these kinds of cheese in relation to their moisture content (ANOVA, $p < 0.001$). The highest moisture content of the cheese samples is characteristic of soft cheese (70.2%), semi-soft cheese (60.5%), semi-hard cheese (52.8%), and hard cheese (45.7%). Similar to authors [87], who indicated that the physicochemical properties of cheese, such as moisture content, fat content, and protein content, play a significant role in defining the texture/rheology of cheese, as well as other authors [54,88–90]. The results obtained are in accordance with international classification systems of cheese that consider the moisture content of the cheese as a significant factor for defining the variety of cheese. Cheeses with higher moisture content have softer texture and shorter ripened period, whereas harder kinds of cheese have longer ripened period and therefore contain less moisture and more solids.

4.3. Influence of Milk Type

Most of the investigated types of cheese were produced using cow milk (54.7%), followed by sheep milk (27.4%), goat milk (12.0%), and mixed milk (6.0%). Compositional differences were noted among the investigated types of cheese produced using different types of milk. Similar findings were reported by the authors [31,54,91,92]. It was noted that the fat and protein contents of the investigated types of sheep milk cheese were higher compared to cow milk cheese. This finding is in accordance with the previous studies indicating that sheep milk has higher contents of total solids and fat. These parameters are considered important for the nutritional and functional characteristics of the produced cheese. The differences in milk composition are considered one of the major factors affecting the physicochemical characteristics of the produced cheese. On the other hand, the investigated types of cow milk cheese had higher moisture contents.

4.4. Correlation Among Physicochemical Parameters

The Pearson correlation analysis revealed that there were some correlations between the different physicochemical parameters. For example, there was a strong negative correlation between the moisture content and fat content ($r = -0.72$), as well as between the moisture content and protein content ($r = -0.65$). This indicated that cheese products with higher moisture content tend to have lower fat and protein content, like what authors [63,86,93]. This is a common phenomenon in dairy science, as explained in the cheese concentration effect during cheese ripening and dehydration. In addition to that, fat content and protein content also showed a strong positive correlation ($r = 0.69$), which indicated that cheese products with high fat content also tend to have high levels of protein. This has also been observed in various studies done on cheese products in terms of their content and

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a moderate positive correlation between salt content (r = 0.55) also indicated that sodium chloride added to cheese contributed to ash content in cheese products, according to authors [72,94,95].

4.5. Multivariate Analysis of Cheese Characteristics

For better understanding of the relationship between the cheese samples, a principal component analysis of the cheese samples with six physicochemical properties, namely moisture, fat, protein, salt, pH, and ash content, has been conducted. From the results, it has been observed that the variations in the cheese samples could be explained by the first two factors, as the variance explained by the two factors in this study was found to be 69.7%. According to similar studies conducted by the authors in their previous research articles, namely [59,69,87,96,97] the variations in the amount of fat and protein content in cheese products have a critical role to play in the quality of cheese products. The first component (PC1) was highly correlated with the content of moisture, fat, and protein and related to the differences between fresh and matured cheeses. The second component (PC2) was mainly correlated with salt, ash, and pH and related to the effects of processing and conditions of ripening, as indicated by the studies carried out by the authors [98–100]. In the field of dairy science, multivariate analysis may be applied for the classification of cheese and for determining the most important factors influencing the product. The results obtained from the analysis of many cheese products have confirmed that the most important factor is the content of moisture, distinguishing fresh and hard cheeses.

4.6. Cluster Analysis and Cheese Grouping

The hierarchical cluster analysis also supported the classification by identifying the different clusters for the 117 cheese samples according to the different types of cheese-soft, semi-soft, semi-hard, and hard cheese. The key factor that affected the clusters was the moisture content of the cheese samples. The fat and protein content also affected the second level of differentiation for the clusters. The importance of moisture and other characteristics of the cheese in the formation of the typology of the cheese has been emphasized by the study. The cluster pattern has been similar in the study that compared the characteristics of the different types of cheese. The study by the authors [4,72,81,101,102].

4.7. Implications for Cheese Standardization and Quality Certification

The findings of this research also offer useful insights into the physicochemical variability of the cheese produced in Kosovo. This variability is an indication of the coexistence of traditional artisanal and newly developed industrial technologies. Although this variability is an important part of the gastronomic tradition in Kosovo, it also indicates the need for standard criteria for classifying cheese to be able to certify quality cheese. Development of standardized parameters of cheese compositions may also help in the development of geographical indications and quality labels. Such systems have been effective in promoting traditional dairy products, making them more competitive in international markets. These findings support by authors [3], [8,9,32,103,104]. Besides this, it may be helpful in determining the most important factors in the composition of cheese, such as moisture content, fat content, and protein content, in developing national standards for cheese in accordance with international regulations in the dairy sector.

5. Conclusions

The general aim of this research was to provide an overview of the physicochemical characteristics of cheese produced in Kosovo and to classify cheese based on the results obtained from the analysis of 117 samples of cheese collected from various areas of cheese production. Based on the research, there are considerable differences in relation to the chemical composition of cheese produced, which is an indication of the variety of traditional methods applied in cheese production.

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This is an indication of the richness of the tradition of production of dairy products in Kosovo and the difficulties encountered in determining the quality criteria of dairy products.

From the physicochemical analysis, it was found that the major factor responsible for differentiation among cheese types is the moisture content, which ranges from 42.5 to 74.5%. Based on the classification criteria adopted universally for cheese types, it is found that the cheese samples have been classified into four types, namely, soft cheese, semi-soft cheese, semi-hard cheese, and hard cheese. It is found that there are major differences in the composition parameters of cheese types in relation to moisture, fat, protein, and salt, which confirms the importance of composition parameters in characterizing cheese type. It is found that the cheese type known as soft cheese contains the maximum moisture and low-fat concentration in comparison to other cheese types, while the hard cheese type contains low moisture and high concentration of solid matter due to ripening.

In this context, the effect of milk type on cheese composition was also investigated in this study. It was found that cheese from sheep's milk had a higher fat and protein content compared to cheese from cow's milk. This is due to differences in the composition of the milk, which in turn affect the cheese composition. Cheeses from goat's milk had intermediate characteristics, yet they had a certain physicochemical profile due to their protein and fat content.

The results of the correlation analysis also revealed that there are significant correlations between some of the physicochemical properties. For example, the moisture content has a significant negative correlation with the fat and protein content. This means that the higher the moisture content in cheese, the lower the content of fat and protein. This result confirms the principles of cheese chemistry, which state that the reduction of moisture content in cheese ripening and processing results in the concentration of other substances in the cheese matrix. The use of multivariate statistical analysis also provided credence to the classification of the different types of cheese.

The key variables responsible for the differences observed in the samples were identified as moisture, fat, and protein content, as determined by principal component analysis, while the results obtained from Cluster Analysis showed that the cheeses could be grouped into four classes, corresponding to the traditional types of cheese. Discriminate analysis also showed that physicochemical parameters could be employed for the discrimination of cheeses according to milk types.

The results obtained in this research may be used as a scientific basis for identifying and classifying the types of cheese produced in Kosovo. Developing standard parameters for physicochemical characteristics and classification criteria may be useful in increasing the quality of cheese products and the quality certification of cheese products. It may be useful in increasing the competitiveness of the dairy sector in Kosovo and the recognition of traditional cheese products in the region and beyond. Future research may be aimed at increasing the number of samples in the database and considering other parameters for classifying cheese products in the region for the sustainable development of the national dairy sector.

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