Application of multiple factor analysis for the descriptive sensory evaluation and instrumental measurements of bryndza cheese as affected by vacuum packaging

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\textbf{ABSTRACT}

Multiple factor analysis was used to examine naturally white, mature and spreadable bryndza cheese varieties. Sensory and physiochemical properties were evaluated during storage in vacuum and non-vacuum packed conditions at 4 ± 2°C. The results of statistical method showed similarity in varieties made from pasteurized ewe milk and mixed bryndza cheese before and after storage at both package conditions (\(p < 0.05\)). The statistical method used in the study was a suitable tool for assessing differences in food quality and provided an opportunity to visualize and categorize the results with regard to shelf life and packaging.

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\textbf{Introduction}

Traditional bryndza cheese is a naturally white, mature and spreadable cheese made in shepherds’ cottages and sheepfolds, with a long tradition in Slovakia. Bryndza cheese is made from ripened sheep lump cheese which can be produced from pasteurized or unpasteurized ewe milk.\textsuperscript{[1]} It can also be made from matured and salted sheep cheese (min. 50% of contents) which is mixed with fresh lump cow cheese from pasteurized milk.\textsuperscript{[2]} “Slovenská bryndza” obtained the “Protected Geographic Indication” designation (PGI) in 2008. Regional products have legally protected names and are made by manufacturing technologies used only in certain regions of the European Union.\textsuperscript{[3,4]}

The sensory quality is now one of the most important attributes for the successful marketing of ewe milk cheeses, but Regulatory Councils often define the sensory characteristics in a vague manner.\textsuperscript{[5]} The information about chemical composition and sensory characteristics of a food product is important for the consumer\textsuperscript{[6]} primarily in the case of a traditional food product. It is very important to study the sensory parameters that define the product using both, an instrumental approach as well as tasting panels, in order to determine its acceptability to consumers. For better control and improvement of food quality, it can be useful to correlate texture properties measured by sensory and instrumental methods\textsuperscript{[7]} as well as colour properties. Products’ packaging allows to preserve their quality, which in the case of cheese implies avoiding dehydration, protecting cheese from undesirable microorganisms, and inhibiting, reducing or allowing continuance of the metabolic activities of ripening strains.\textsuperscript{[8]} The quality of bryndza cheese including composition, physicochemical properties and microbial diversity depends on the quality of ewe milk.\textsuperscript{[9–12]} The special taste and
textural parameters of traditional cheese specialties could make them popular.\textsuperscript{13} However, neither any studies on sensory descriptive analysis of traditional bryndza cheese are published, nor supportive instrumental analyses of texture and colorimetry or vacuum packaging are available. Also, the request for PGI registration of “Slovenská bryndza” does not provide a detailed terminology of bryndza cheese sensory characteristics.

The sensory quality of a product, for example, dairy products like bryndza cheese, can be evaluated using quantitative descriptive analysis.\textsuperscript{14} This method describes all sensations perceived when evaluating a product sample. Each of its sensory properties, such as appearance, odour, texture and flavour, is assessed using several descriptors that are then quantitatively measured using an appropriate scale.\textsuperscript{7}

Multiple factor analysis (MFA) is an alternative to principal component analysis (PCA)\textsuperscript{15} allowing to balance the role of the two sets of variables and giving visualization tools and indices that can be helpful for researchers.\textsuperscript{16} It is a very well-established method dealing with data table where a set of individuals is described by several sets of variables.\textsuperscript{16–18} In general terms, PCA uses a vector space transform to reduce the dimensions of large data sets.\textsuperscript{19} The presented study deals with two sets of variables (sensory and instrumental data). The main advantage of MFA is that it reveals any latent variables that cause the manifest variables to covary, while PCA does not discriminate between shared and unique variance.\textsuperscript{20} Application of MFA was used in recent sensory studies, for example in chocolate milk desserts\textsuperscript{21}, milk spoilage\textsuperscript{22}, and development of functional yogurts.\textsuperscript{23} The aim of this study was to apply the method of MFA to evaluate the textural, colour and sensory characteristics related to three bryndza cheese varieties manufactured according to the traditional method of production during storage period under different package conditions.

**Material and methods**

**Sampling**

To study the quality of bryndza cheese, three consecutive batches from the following bryndza cheese samples were evaluated:

- BU (bryndza cheese made from 100% sheep lump cheese manufactured from unpasteurized ewe milk),
- BP (bryndza cheese made from 100% sheep lump cheese made from pasteurized ewe milk), and
- BM (bryndza cheese made from a mixture (50:50) of sheep lump cheese with lump cow cheese from pasteurized milk).

A total of 162 bryndza cheese samples were evaluated in this study. From each bryndza cheese variety (BU, BP and BM), 54 samples were randomly selected on the initial day of manufacture and divided into the following groups:

- the first group consisted of initial samples ($n = 18$) which were analyzed before storage period (BS, Figure 1 A),
- the second group contained samples ($n = 18$) that were placed in plastic bags to prevent desiccation, but exposed to normal atmosphere conditions and stored for 14 days at the temperature of $4 \pm 2^\circ C$ (non-vacuum-packed samples – NP, Figure 1 B),
- the third group consisted of individually vacuum packed samples ($n = 18$) in plastic bags and stored for 14 days at the temperature of $4 \pm 2^\circ C$ (vacuum-packed samples – VP, Figure 1 C).

Plastic bags used in NP and VP sample groups were made from polyethylene with thickness of 70 µm (G-PACK, LLC., Slovak Republic) and Boss Vacuum machine (NE 2746 N, Germany) was
Figure 1. (A) Bryndza cheese samples before storage; (B) bryndza cheese samples after storage in non-vacuum-packed conditions; (C) bryndza cheese samples after storage in vacuum packed conditions.

BU, bryndza cheese made from unpasteurised ewe milk; BP, bryndza cheese made from pasteurised ewe milk; BM, bryndza cheese made from unpasteurised ewe milk with addition of cow lump cheese from pasteurised milk (50%); BS, before storage; NP, after the 14th day of storage without packaging; VP, after the 14th day of vacuum packaging storage.
used to package each VP sample in vacuum conditions. All bryndza cheese varieties were produced in compliance with the traditional methods of production in a dairy plant according to the processing procedures described in the “Method of production” for PGI registration of “Slovenská bryndza” cheese.\cite{2}

**Physicochemical analysis**

The chemical composition of bryndza samples was determined using standard procedures: pH, dry matter (DM)\cite{24}, fat\cite{25}, proteins according to Kjeldahl\cite{26}, NaCl content according to Mohr argentometric titration.\cite{27} For the purpose of objective evaluation, the results were expressed as protein in dry matter (P/DM), fat in dry matter (F/DM), and salt in moisture (S/M), while moisture content was calculated after determination of dry matter in cheese after drying. Determinations of physicochemical composition were performed in triplicate.

**Colour measurement**

Surface colour of the bryndza cheese samples was analyzed. Colour was measured by a Chroma meter CR-410 (Minolta, Osaka, Japan) using CIELAB L*a*b* values.\cite{28} For the measurement of colorimetric data, Chroma meter CR-410 (measurement area $\varnothing$ 50 mm, illuminance D65, standard observer angle 2°, Konica Minolta, Sensing, Inc., Japan) and Colour Data Software CM-S100w SpectraMagic™ NX (Konica Minolta Sensing Inc., Osaka, Japan, 2014) were applied. The Chroma meter was standardized using a white standard plate (CR-A43, Konica Minolta). The results reported are average values of the three measurements of each bryndza cheese sample surface.

**Instrumental texture profile analysis (TPA)**

The texture profile analysis was performed using TA-XT Plus Texture Analyzer (Stable Micro System, Surrey, UK) according to Šnirc et al.\cite{29} with modifications. The tested sample dimensions were $25 \times 25 \times 25$ mm. The samples were examined using a Stable Micro Systems Type (version 9.0). Heavy duty platform with aluminium plate was installed and a 5 kg weight was used to calibrate the 25 kg load cell prior to the analysis and the setting was adjusted at a pre-test speed of 1 mm·s$^{-1}$, a test speed of 2 mm·s$^{-1}$ and a post-test speed of 10 mm·s$^{-1}$. All the samples were compressed using a cylindrical probe to a target distance of 10 mm. The measurements were made at ambient temperature ($20 \pm 2^\circ$C). The obtained texture profiles were used to measure the instrumental hardness and stickiness of bryndza cheese samples.

**Sensory analysis**

Samples were received from the dairy plant in plastic bucket containers and stored at $4 \pm 2^\circ$C until use. The cheeses were portioned into $25 \times 25 \times 25$ mm cubes with approximate weight of 25 g using a wire slicer, served in white plastic dishes and coded with three-digit random numbers. Samples were served at $18^\circ$C (temperature of consumption $20 \pm 2^\circ$C). Mineral water was provided for mouth-rinsing.

**Descriptive analysis**

The descriptive sensory evaluation was carried out in a standardized sensory laboratory\cite{30} built in the Institute of Postgraduate Education of Veterinary Medicine in Košice according to Lawless and Heymann.\cite{14} The sensory evaluation was performed by a panel from the staff of the University of Veterinary Medicine and Pharmacy in Košice. Panelists participated in 12 training sessions and evaluated the samples. The group contained 18 panellists aged between 28 and 65. All the assessors were trained in the sensory analysis of ewe milk cheese prior to the analysis. During the first part of
the training period, assessors attended a number of group sessions in which they tasted bryndza cheese samples and generated descriptors. Description terminology for the sensory attributes of bryndza cheese was introduced during the training sessions. Descriptors for appearance (white, smooth paste, fine grained, lumpy), aroma (sour, ovine, yeasty, milk fat, dank, pungent, putrescent), taste (delicious, sheep cheese taste, spicy, pleasantly acidic, salty, bitter, musty) and consistency (spreadable, firm, cohesive, soft, sticky, curdy, friable, shapeable) were selected.

After the training period, the panel evaluated three varieties of bryndza cheese manufactured according to the traditional methods of production. Subsequently, NP and VP samples were evaluated after the 14th day by the same panel. Assessors were requested to evaluate the intensity of each descriptor by assigning the score on a 10 point linear scale (0 – absence of sensation and 10 – extremely intense).

**Statistical analysis**

Data analysis was carried out with R – statistics software. A two-way analysis of variance (ANOVA) and Tukey test for multiple comparison of means with a confidence interval set at 95% was conducted. The differences between bryndza cheese varieties and the effect of storage with and without vacuum packaging were set as the main factors. MFA was conducted in R – statistics software with “FactomineR” and “factoextra” package. A spider web plot was generated using “fmsb” package.

**Results and discussion**

The results of physicochemical determinations are presented in Table 1. The coefficient of variation in the results of each physicochemical parameter ranged in BS, NP and VP cheese samples between 3.85%–33.35%, 2.77%–26.78% and 1.94–36.22%, respectively. The highest coefficient of variation in physicochemical results was observed in the parameter of S/M, which was over 30% in BU (BS and

| Parameter                  | Storage       | BU      | BP      | BM      | Variety (V) | Storage (S) | Interaction (V × S) |
|----------------------------|---------------|---------|---------|---------|-------------|--------------|--------------------|
| pH                         | BS            | 5.13 ± 0.31<sup>Aa</sup> | 5.13 ± 0.26<sup>Aa</sup> | 5.21 ± 0.29<sup>Aba</sup> | < 0.01 | 0.119 | 0.164 |
|                             | NP            | 5.25 ± 0.28<sup>Aa</sup> | 5.02 ± 0.27<sup>Ab</sup> | 5.34 ± 0.22<sup>Aa</sup> | 0.119 | < 0.001 | 0.013 |
|                             | VP            | 5.11 ± 0.24<sup>Aa</sup> | 5.07 ± 0.19<sup>Ab</sup> | 5.13 ± 0.21<sup>Aa</sup> | < 0.001 | < 0.001 | < 0.01 |
| Dry matter [%]              | BS            | 49.78 ± 1.93<sup>Aa</sup> | 47.80 ± 1.96<sup>Ab</sup> | 47.08 ± 4.51<sup>Aa</sup> | < 0.001 | < 0.001 | < 0.01 |
|                             | NP            | 65.65 ± 3.53<sup>Ba</sup> | 58.26 ± 6.30<sup>Bb</sup> | 57.67 ± 3.63<sup>Ba</sup> | 0.119 | < 0.001 | 0.048 |
|                             | VP            | 50.63 ± 1.18<sup>Aa</sup> | 47.57 ± 2.54<sup>Ab</sup> | 44.86 ± 0.90<sup>Bc</sup> | < 0.001 | < 0.001 | < 0.001 |
| Protein in dry matter [%]   | BS            | 41.21 ± 4.49<sup>Aa</sup> | 38.82 ± 2.41<sup>Ab</sup> | 40.27 ± 4.71<sup>Aa</sup> | < 0.001 | < 0.001 | < 0.01 |
|                             | NP            | 40.91 ± 3.34<sup>Aa</sup> | 36.52 ± 3.21<sup>Ab</sup> | 43.02 ± 1.51<sup>Aa</sup> | 0.119 | < 0.001 | 0.048 |
|                             | VP            | 38.10 ± 2.50<sup>Aa</sup> | 37.98 ± 1.70<sup>Ab</sup> | 40.43 ± 2.49<sup>Aa</sup> | < 0.001 | < 0.001 | < 0.001 |
| Fat in dry matter [%]       | BS            | 51.45 ± 2.50<sup>Aa</sup> | 52.89 ± 2.09<sup>Ab</sup> | 50.81 ± 3.92<sup>Ba</sup> | < 0.001 | < 0.001 | < 0.001 |
|                             | NP            | 51.30 ± 3.89<sup>Aa</sup> | 55.87 ± 3.26<sup>Ba</sup> | 48.81 ± 1.39<sup>Aa</sup> | 0.119 | < 0.001 | 0.048 |
|                             | VP            | 54.37 ± 1.71<sup>Aa</sup> | 53.31 ± 1.49<sup>Ba</sup> | 50.34 ± 1.39<sup>Ba</sup> | < 0.001 | < 0.001 | < 0.001 |
| Salt in moisture [%]        | BS            | 4.39 ± 1.51<sup>Aa</sup> | 5.55 ± 1.22<sup>Ab</sup> | 5.48 ± 0.34<sup>Ba</sup> | 0.403 | < 0.001 | < 0.001 |
|                             | NP            | 9.89 ± 1.32<sup>Ba</sup> | 7.95 ± 2.19<sup>Bb</sup> | 8.53 ± 0.55<sup>Bb</sup> | < 0.001 | < 0.001 | < 0.001 |
|                             | VP            | 5.33 ± 1.99<sup>Aa</sup> | 5.09 ± 0.92<sup>Ab</sup> | 4.91 ± 0.88<sup>Aa</sup> | 0.403 | < 0.001 | < 0.001 |

BU, bryndza cheese made from unpasteurised ewe milk; BP, bryndza cheese made from pasteurised ewe milk; BM, bryndza cheese made from unpasteurised ewe milk with addition of cow lump cheese from pasteurised milk (50%); BS, before storage; NP, after the 14th day of storage without packaging; VP, after the 14th day of vacuum packaging storage; V, the main effect of bryndza cheese variety; S, the main effect of storage in vacuum and non-vacuum packed bryndza cheese samples; V × S – interaction effect between varieties and storage;<sup>A–C</sup>, in a column means (storage conditions) without a common superscript letter differ (p < 0.05);<sup>a–c</sup>, in a row means (cheese variety) without a common superscript letter differ (p < 0.05).
VP) and over 20% in BP bryndza cheese variety (BS and NP). This could indicate unequal distribution of salt in cheese during processing. There were coefficients of variation lower than 5% in pH parameter in all the VP cheese varieties, and also in non-packed BM bryndza cheese. Other physicochemical measurements of bryndza cheese varieties during storage ranged in coefficients of variation between 5% and 30%.

Moisture content and acidity are regarded the two most important factors in the control of cheese properties. Generally, a firm, low-moisture cheese will result in a slower rate of ripening, more selective microflora activity, milder flavour and longer product keeping quality. Dry matter in cheese could be increased by adding calcium salts, higher temperature at renneting, higher content of proteins in milk, faster process of fermentation, etc. On the other hand, lower addition of calcium salts or lower temperature at renneting or early addition of salt to cheese could cause a decrease of dry matter in the final cheese.

Many properties of dairy products depend on the size and distribution of fat globules and the composition of their membrane. Fat content, higher dry matter and higher protein content was observed in ewe milk than in cow milk. When large amounts of salt are added to curd during cheese manufacture, the ability of starter bacteria to metabolize lactose to lactic acid is impaired, which would also contribute to stabilizing the cheese pH. The concentration and distribution of salt in cheese affect the syneresis of cheese curd and thus reduce the moisture of cheese, which also influences the activity of microorganisms and enzymes.

Statistically significant differences were observed in physicochemical parameters between vacuum and non-vacuum packed samples after storage in DM and S/M (p < 0.05). VP samples reached similar values to BS indicating that VP is recommendable for storage of bryndza cheese, except for bryndza cheese made from unpasteurized ewe milk. Our results of physicochemical measurements of bryndza cheese samples corresponds to Kerestes and Selecký who reported average values of 50% of moisture, 25% of fat, 20% of proteins, and 3% of anorganic salts in bryndza cheese. Activity of water and pH are the most important factors influencing the cheese stability. Our obtained results of pH determination in bryndza cheese varieties are comparable to other authors.

Tables 2 and 3 illustrate data of the colour and textural parameters, respectively. During this experiment, coefficients of variations lower than 10% were observed in all bryndza cheese varieties. Colour measurements may be used to evaluate colour changes in foods, especially in cheese. Objective expression of colour parameters was performed in CIELAB colour space. The L* value represents lightness, a* redness (colour between red and green), and b* is yellowness (between blue and yellow). The a* and b* combination determines the parameter of hue angle (h* values) which gives the predominant wavelength composing the colour and chroma (C* values) that accounts for the vividness or the colour purity. Statistically significant effect of storage under different packaging conditions was found in all bryndza cheese varieties (p < 0.001). However, in comparison of bryndza cheese varieties at the initial stage of storage (BS), a statistical difference in L* parameter (p > 0.05) between samples was not observed. Based on our obtained results, we could agree with observations by Eroglu et al. that the increase of dry matter in cheese can contribute to colour changes in non-vacuum packed samples in contrast to vacuum packed samples during storage, where significant differences between non-vacuum–packed and vacuum-packed samples of cheese were observed. The increase of L* values in vacuum packed cheese samples was believed to be caused by not losing water in the package during the storage period resulting in conservation of the initial white colour during the storage period. In their work, Tarakçı and Durmuş studied effects of packaging materials on colour of cheese and found that plastic packaging material caused higher L* values of the cheese. Their findings correspond to our measurements of colour changes during storage of BN, BP and BM bryndza cheese varieties. Microbiota in bryndza cheese is represented also by Geotrichum candidum and by other microbial species that can affect sensory properties. Dufossé et al. studied the ripening process and quality of red smear soft cheeses protected by the Protected
The results of our physicochemical parameters of bryndza cheese samples, we can agree with the conclusions by Fox et al. who studied hardness in nine industrial bryndza cheeses made from pasteurized ewe milk. According to our results, bryndza cheese made from unpasteurized ewe milk was softer and less sticky than bryndza from pasteurized ewe milk and mixed bryndza. Fox et al. observed that high values of moisture and pH and a low salt level lead to flavour and textural defects. Consistency is an important viscoelastic property of the product. According to our physicochemical parameters results of bryndza cheese samples, we can agree with the conclusions by Fox et al. that salt in cheese can influence protein solubility, probably protein conformation, cheese texture, and functionality. Proteolysis is probably the most important biochemical event having a major impact on flavour and texture of most cheese varieties. In each bryndza cheese variety (BN, BP, BM), the main effect between varieties and storage; S, the main effect of storage in vacuum- and non-vacuum-packed bryndza cheese samples; V × S, interaction effect between varieties and storage; a–c, in a row means (cheese variety) without a common superscript letter differ (p < 0.05); a–c, in a column means (storage conditions) without a common superscript letter differ (p < 0.05).
and BM), hardness of samples after storage increased in non-vacuum packed conditions. In general, it can be caused by evaporation of water. Likewise, hardness of bryndza cheese samples after vacuum packed storing was higher than hardness measured in BS samples, and, interestingly, also higher than hardness in NP bryndza cheese. The higher results of VP samples were probably due to air removal and pressure force which the packaging material exerted on the cheese sample during vacuum packaging that compacted the bryndza cheese matter.

Graphical presentation of the sensory data commonly involves using “cobweb” graphs\cite{14} also known as radar or spider web plots. Superimposing of spider plots can be used to compare products with each other or to compare attribute intensities of a single product tested at different points in time.\cite{55} The spider plot of each bryndza cheese variety before storage and their non-vacuum packed and vacuum-packed samples after storage is presented in Figure 2.

Statistically significant differences among bryndza cheese varieties were observed in each evaluated descriptor ($p < 0.001$) with lower significance in salty taste ($p < 0.05$) and except for spicy taste where significance was not observed ($p > 0.05$). Bryndza cheese, especially the variety made from unpasteurized ewe milk is characterized by very intensive aroma and taste, which could be caused by

![Figure 2. Sensory profile of bryndza cheese samples during storage.](image)

BU, bryndza cheese made from unpasteurised ewe milk; BP, bryndza cheese made from pasteurised ewe milk; BM, bryndza cheese made from unpasteurised ewe milk with addition of cow lump cheese from pasteurised milk (50%); BS, before storage; NP, after the 14$^{th}$ day of storage without packaging; VP, after the 14$^{th}$ day of vacuum packaging storage.
the activity of the presented microbiota participating in it. The microbiota in raw ewe milk is represented mainly by *Lactobacillus* spp., *Enterococcus* spp., *Lactococcus* spp., *Streptococcus* spp., *Kluyveromyces marxianus*, and *Geotrichum candidum*.

Descriptive sensory analysis performed on bryndza cheese samples demonstrated statistically significant influence of storage in NP and VP samples on the intensities of sensory descriptors of appearance: smooth paste and lumpy; descriptors of aroma: sour, ovine, yeasty, milk fat, dank, pungent, putrescent; descriptors of taste: delicious, sheep cheese taste, pleasantly acidic, salty, bitter, musty; and descriptors of consistency: spreadable, firm, cohesive, soft, sticky, curdy, and friable (*p* < 0.001). It has been reported that the use of modified atmosphere packaging for dairy products with high percentages of CO₂ may have a detrimental effect on the sensory properties, especially with regard to flavour. The results of our study showed that vacuum packaging was suitable for bryndza cheese varieties when compared with non-vacuum packed samples. In bryndza cheese samples, vacuum packaging after the storage period reduces the intensity of inconvenient sensory descriptors which were more intensive and for some evaluators repulsive in NP samples (e.g. bitter and musty taste, pungent and putrescent aroma).

In this study, we presented a relatively high amount of sensory descriptive data and their visualization through a commonly used method of spider plots was considered difficult from the point of view of results interpreting and contrasting between bryndza cheese varieties and the effect of storage under different packaging conditions. Because of that, MFA proved to be an applicable, fast, and suitable method for the purposes of studying the descriptive sensory data supplemented with instrumental measurements as well as physicochemical parameters.

In our study, MFA method was applied to the data of sensory descriptive analysis, colorimetric and textural instrumental measurements, and physicochemical parameters, whereas bryndza cheese varieties and storage under different packaging conditions presented the main factors. The analysis extracted the most significant variables with a minimum loss of information. Kaiser’s criterion (eigenvalue > 1) was applied to determine the number of final factors from the initial ones. The results of MFA showed four selected components that explain more than 77% of the total variation in the dataset. The first dimension (Dim1) explains 36.91% of variation, dimension 2 (Dim2) 17.43%, dimension 3 (Dim3) more than 13%, and dimension 4 (Dim4) 9.97%.

During cheese ripening, many biochemical and chemical changes occur, which contribute to the formation of the characteristic taste and aroma of the cheese. Contribution of the analyzed data in Dim1 related to sensory descriptors of aroma (17.40%, *r* = 0.96), taste (17.17%, *r* = 0.96), consistency (17.01%, *r* = 0.95) and instrumental colour parameters (13.50%, *r* = 0.85). The highest contribution in Dim1 included descriptors of taste: bitter (*r* = 0.92), musty (*r* = 0.91), spicy (*r* = −0.19), sheep cheese taste (*r* = −0.60), pleasantly acidic (*r* = −0.72) and delicious taste (*r* = −0.90) which correlated at statistically significant level (*p* < 0.001). The following descriptors of aroma correlated in Dim1: putrescent (*r* = 0.96), yeasty (*r* = 0.94), dank (*r* = 0.89), sour (*r* = 0.85), pungent (*r* = 0.82), ovine (*r* = 0.74) and milk fat aroma (*r* = −0.54). Correlations between consistency descriptors: sticky (*r* = 0.94), friable (*r* = 0.89), firm (*r* = 0.83), curdy (*r* = 0.75), shapeable (*r* = −0.41), spreadable (*r* = −0.87), cohesive (*r* = −0.90) and soft (*r* = 0.93) were also observed in Dim1.

The sensory characteristics of “Slovenská bryndza” cheese described in the request for PGI registration are typical for bryndza cheese but not detailed. It is characterized by a delicate odour and taste and it has a pleasantly sour sheep cheese taste that is slightly spicy and salty. Ortigosa et al. noted that pasteurization in Roncal type cheese from ewe milk decreased the level of microorganisms and even eliminated some of them, such as facultatively hetero-fermentative lactobacilli, and because of that odour and aroma of the cheeses were affected. It has also been pointed out that the effect of endogenous microbiota of milk on sensory properties of raw milk cheeses is greater than on those made from pasteurized milk.

Dim2 was characterized by the contribution of the textural parameters (26.26%, *r* = 0.81), appearance descriptors (24.14%, *r* = 0.78) and bryndza cheese varieties (19.08%, *r* = 0.69) with storage under different packaging conditions (16.11%, *r* = 0.63). Descriptors of appearance: white
(\(r = 0.74\)), fine grained (\(r = 0.69\)), smooth paste (\(r = 0.68\)) and lumpy (\(r = 0.62\)) correlated in Dim2. The obtained correlation coefficients of 0.79 and \(-0.80\) of textural parameters in Dim2 were observed for hardness and stickiness, respectively.

The first two dimensions explained a total of 54.33% of variance (Figure 3). Physicochemical parameters contribute mainly to Dim3 with 26.26% and correlation coefficients for physicochemical parameters were determined as follows: P/DM (\(r = 0.54\)), S/M (\(r = 0.36\)), pH (\(r = 0.36\)), DM (\(r = 0.31\)) and F/DM (\(r = -0.61\)) at a statistically significant level (\(p < 0.001\)).

From the obtained results of MFA analysis, we can conclude, that each bryndza cheese variety was relatively analogous before storage, but there were the distinctions mentioned above. The visualized plot of individuals (Figure 3) clearly identified this analogy in bryndza cheese varieties before and after storage period.

Similarity of bryndza cheese in the analyzed parameters was observed between BP and BM samples after VP storage, and also between BP and BM samples after storage without vacuum packaging. NP and VP samples were different from other bryndza cheeses and also from each other. These groups were not plotted closely to each other. As far as bryndza cheese is concerned, it can be made by mixing ewe and cow lump cheese (max. 50% of cow lump cheese contained).\(^2\) The price of ewe milk is higher than that of cow milk.\(^61\) In this case it is important to recognize traditional cheese specialties where cow

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**Figure 3.** Multiple factor analysis plot of bryndza cheese varieties individuals during storage. BU, bryndza cheese made from unpasteurised ewe milk; BP, bryndza cheese made from pasteurised ewe milk; BM, bryndza cheese made from unpasteurised ewe milk with addition of cow lump cheese from pasteurised milk (50%); BS, before storage; NP, after the 14th day of storage without packaging; VP, after the 14th day of vacuum packaging storage.
milk is not allowed in the mixture due to possible adulteration. Dishonest producers could use a higher proportion of cow lump cheese than permitted in bryndza cheese production, especially in the mixed bryndza cheese variety, or in bryndza cheese made from 100% pasteurized or raw ewe milk. In such case, official inspections of foodstuffs have to analyze bryndza cheese samples in a laboratory, for example by detecting cow β-lactoglobulin \(^\text{[62]}\), in order to disclose possible falsification.

Analysis of variance (ANOVA) is the most frequently used statistical method to compare mean values of two or more groups.\(^\text{[63]}\) We used the Two-way ANOVA in Tables 1, 2 and 3, when two independent variables (storage and variety) were affecting a dependent variable (parameter). However, ANOVA cannot provide detailed information on differences among the various studied groups, or on complex combinations of the studied groups.\(^\text{[64]}\) To fully understand group differences in ANOVA, researchers must conduct tests of the differences between particular pairs of experimental and control groups called post hoc tests or multiple comparison tests (i.e. Tukey, Newman-Keuls, Scheffe, Bonferroni and Dunnett), but each of them has specific uses, advantages and disadvantages.\(^\text{[64]}\)

On the other hand, MFA is an analysis applied to tables in which a set of individuals is described by several groups of both, categorical and quantitative variables.\(^\text{[65]}\) The core of MFA is a weighted PCA which allows to balance the influence of each group of variables in the analysis.\(^\text{[66,67]}\) The idea of the weighting in MFA is in the same vein as the standardization in PCA where identical weight is given to each variable to balance their influence. A clustering performed on the first principal components issues in MFA allows to create a clustering balancing the influence of each group of variables.\(^\text{[66]}\) MFA proceeds in two steps: First it computes a PCA of each data table and ‘normalizes’ each data table by dividing all its elements by the first singular value obtained from its PCA.\(^\text{[15]}\) PCA can be used for continuous data and MFA for data structured in groups of variables.\(^\text{[67,68]}\)

We can conclude that three traditional methods of bryndza cheese production and physicochemical composition of bryndza cheese related to raw milk quality used in cheese processing did noticeably influence the sensory parameters of the final product. The main advantage of the MFA method in this study was the indication of sensory descriptors and other determined parameters that significantly differentiated the quality of bryndza cheese varieties during storage period under different packaging conditions (Figure 4). Overall, it also characterized parameters which are positively or negatively correlated to each other. The analysis of sensory profile of the cheeses permits identification of specific attributes that could have impact on consumers’ preferences, expectation, and choice.\(^\text{[69]}\) In this study, a specific terminology for sensory analysis of bryndza cheese was established, which should be implemented into systematic monitoring of its quality. For this purpose, the MFA method proved to be a very convenient, appropriate, and useful tool for sensory assessment of bryndza cheese taking into consideration instrumental measurements of colour, texture as well as physicochemical parameters.

**Conclusion**

The results of sensory assessment by the method of MFA showed similarity of bryndza cheese varieties at the beginning of storage period. After the storage period, resemblance was observed within the group of non-vacuum packed samples between bryndza cheese made from pasteurized ewe milk and mixed bryndza cheese variety and within the group of vacuum packed samples between the same varieties. High diversity from other groups was detected in bryndza cheese variety made from unpasteurized ewe milk after storage in vacuum and non-vacuum packaging. Implementation of vacuum packaging for storage of all bryndza cheese varieties could be a beneficial method of packaging in bryndza cheese processing that can stabilize physicochemical and sensory parameters, but further analysis, e.g. microbial, will be necessary. The Multiple Factor Analysis method was a very useful and effective statistical tool for sensory assessment of bryndza cheese varieties stored in different packaged conditions, supplemented with both, instrumental measurements and physicochemical determinations as well.
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