Analysis of the milk raw materials used in the production of Dorna Swiss cheese in different seasons

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Abstract

Introduction. The objective of this work consists of the analysis of the chemical and hygienic-sanitary properties of the milk used in the production of Dorna Swiss cheese in two seasons, along with the documentation of the technology particularities.

Materials and methods. The milk samples used in Swiss cheese manufacturing were analyzed in two seasons (summer and winter) for the chemical composition, pH, and hygienic-sanitary parameters. Correlations and Principal Component Analysis were employed to study the relationships between variables.

Results and discussion. The main particularity in the processing of Dorna Swiss cheese can be summarized as the coagulation in copper tanks of a mixture of unpasteurized milk (70%) with slow pasteurized milk at 65 ºC (30%). The chemical composition and the hygienic-sanitary indices of the milk raw material are crucial for obtaining a high-quality Swiss cheese product. The evolution of the main chemical properties of milk raw material revealed important variations in the summer and winter seasons, regarding the fat, total protein, and casein content. The total somatic count values were higher in the summer season than in winter (201.75×10^3 *vs.* 78.45×10^3 cells/mL). The total bacteria count also presented low values, with very tight oscillations in the summer and winter seasons (81.70×10^3 vs. 87.65×10^3 cfu/mL), which were lower compared to those presented in the European standards. The fat content in summer ranged from 3.32 to 4.67% and in winter from 3.86 to 3.25%. Significant differences ($p < 0.05$) regarding the protein and casein contents were observed between seasons (3.15% and 2.55%, respectively, in summer *vs.* 3.32% and 2.68%, respectively, in winter). The lactose content was higher in the summer (4.62%) compared to the winter period (4.25%). The total dry matter and non-fat dry matter of milk registered lower values in summer compared to winter (11.98% and 8.54%, respectively vs. 12.86% and 8.95%, respectively). The milk samples showed lower pH values in the summer (6.37) compared to winter (6.60), the difference being significant at $p < 0.05$. According to the results, significant correlations ($p < 0.05$) were obtained between the chemical characteristics of milk and season. The overall analysis of the main chemical compounds and sanitary indices of milk raw material revealed small individual variations, which eliminates any risk of affecting the producer, processor, or consumer.

Conclusion. The evolution of hygienic-sanitary parameters of milk showed that they are in agreement with the current standards. The particularities of the Dorna Swiss cheese production are a mix of milk raw material quality and the use of copper tanks, along with slow partial pasteurization which contributes to the unique final product characteristics.

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Introduction

Emmental cheese is known throughout the world as "Swiss-type" cheese, a name found in the United States, Canada, New Zealand, and Australia (Thierry et al., 2010). The Codex Alimentarius (CODEX STAN 269-1967) of the United States defines Emmental cheese as a mature cheese of hard consistency in the form of wheels, weighing 40 kg or more, with an elastic texture and with holes ("eyes") having sizes varying from those of a cherry to of a walnut (FAO, 2007). Emmental cheese production dates back to the 13th century, having been obtained for the first time in the valley of the Tal mountain, on the river Emme, in the Swiss canton of Bern. Currently, "Swiss" type cheese is internationally recognized (Fröhlich-Wyder and Bachmann, 2004) and is frequently considered a traditional product in many European countries, such as France, Germany, Austria, Ireland, and Finland (Bisig et al., 2010). In Romania, this variety of cheese is mainly represented by Dorna Swiss, produced in the mountainous area of Dorna, an area where Pinzgau cattle and a great diversity of pastures and hayfields still exist. This product also contains biologically active compounds originating from soils rich in deposits of manganese, iron, and copper which pass through the soil-plant-animal chain into milk and dairy products and provide the high nutritional value of Emmental cheese.

Swiss cheese is an extremely valuable assortment of matured cheese, obtained from cow's milk, which is presented in the form of a hard paste, with a sweet, pleasant taste and specific aroma, with a very long shelf life (Necula and Babii, 2012). The production of a high-quality Swiss cheese depends on the quality of the milk, the climatic conditions of the area, the professional training and experience of the processor and the staff involved, as well as some specific spaces, equipment, and installations. The quality of the fodder is also essential, with the best milk coming from cows raised in mountain areas located at over 800 m altitude, where the basic fodder is grass, grazed during the summer, or administered as hay during the stable period. This constitutes a very good feed, aromatic, easily digestible, and rich in protein, mineral salts, and vitamins, which ensures superior quality of the milk obtained (Leniuc, 2015). It is also important that fresh milk gets processed as quickly as possible and is not allowed to be transported over long distances, which can lead to its depreciation and, as a consequence, a decrease in the quality of the final product (Leniuc, 2015).

Dorna geographic area has a tradition in the processing of cheeses, especially Swiss cheese. Historical documents attest to the fact that in 1827, in Vatra Dornei, a Swiss industrialist, Otto Stacker, established the "Alpina" cheese factory equipped with high-performance machinery for that period, which is presented in an article in the local Vatra Dornei newspaper, since 1936. It had the capacity to process 10,000 L of milk/day, in different assortments of cheeses, including 3 types of Emmentaler, 3 types of Holland, Petit-Gryere, Blockfromage, Trappist, Gervais, and Camembert, intended for the domestic market and for export (the Dorna monitor August 23, 2017). We also mention that in 1937 a developer established the "Nufărul" cheese factory in Vatra Dornei, which processed Emmentaler as the main product. In 1948, the Enterprise for the Collection and Industrialization of Milk was established, being founded with the equipment from the Alpina and Nufarul factories and developed through national investment funds.

Among the basic conditions necessary to obtain a high-quality Swiss cheese, it should be mentioned that the cows' feed must not contain fermented fodder, and the maturation period of the cheeses must be at least 90 days. The rules of good practice must also be respected: the distance and time of transport as well as the storage time should fall within a maximum of 24 hours, in the case of the Swiss cheese. An element of safety is also the veterinary sanitary control carried out by the Romanian Veterinary Sanitary and Food Safety Agency (ANSVSA), which analyzes from a microbiological point of view the water, milk and cheese samples every month. The analysis of the samples consists in evaluating the presence and count of *Esherichia coli,* coliform bacteria, *Clostridium perfringens,* and intestinal enterococci. In the case of milk, compliance with the current European norms regarding total somatic cell count and total bacteria count is evaluated. The examinations of the cheese are focused on establishing the degree of contamination regarding the load with coagulo-positive staphylococci.

Nowadays, mountain agriculture in the Dorna area is reduced compared to the communist period (1947–1989), with the main producers being small farms or familial households (Jujea, 2023). However, there are two certified producers in the Dorna area trying to resurrect the Swiss cheese production tradition. Their main problem in the manufacturing process is the quality of milk raw material. To our knowledge, there are no papers presenting the processing technology of Dorna Swiss cheese and the quality parameters of the milk raw material used.

Considering the above-mentioned facts, the *aim* of research was to document the technological process of Dorna Swiss cheese production and to evaluate the chemical and microbiological characteristics of the milk raw material.

Materials and methods

Materials

The research was carried out between June 2021 and April 2022 on dairy products obtained in a factory authorized for the production of Swiss cheese and Raclette in the Dorna geographic area. The research consisted of conducting documentation and investigations on the compositional and hygiene-sanitary indices of the milk raw material, as well as the technological procedures for processing an assortment of Dorna Swiss cheese, specific to this commercial unit.

Description of the studied factory

The factory was sanitary and veterinary authorized (based on law 84/1998) and registered in the Trade Register (under the I.I. Țăranu Cristian brand), being regulated to use the Călimani "Mountain Product" logo. In the Dorna area, there is a cooperative called "Caș ca Șarul Dornei", which gathers milk from most farmers to deliver it to the major processors in the country. From this, the processors first select the milk necessary for the production of the Swiss cheese. At the reception of the milk, an expeditious summary analysis is made of each can, with 70% alcohol to detect acidified milk and with R-mastitest reagent to detect milk provided by cows with mastitis. The milk that meets the standards at the first preliminary examination is submitted to the analysis with the Eco Milk device, for the evaluation of some compositional parameters (fat and total protein) and physical parameters (density, cryoscopic point, and acidity), and the antibiotic content with the Biokom device. In the end, the milk samples with increased acidity remain at the cooperative to be directed to the processing of other products, and the ones with antibiotic content are returned to the farmers.

Methods

Technology documentation

The technological process of Dorna Swiss cheese was analyzed by observing the production steps and by underlying the particularities.

Milk characteristics

Samples of milk raw material (n = 20) were collected, from cans selected from the Cooperative intended for Swiss processing, which were investigated at the Foundation's Milk Control Laboratory in Cluj Napoca. The tests were carried out on milk samples collected in 2 seasons (summer, 2021 and winter, 2021-2022), using equipments such as: Milkoscan (model 7 RM, FOSS Analytical, Denmark) for the determination of physico-chemical parameters, Fossomatic (FOSS Analytical, Denmark) for the determination of total somatic cells count and BactoScan FC (model 73710, FOSS Analytical, Denmark) for the determination of total bacteria count. Thus, in the case of the investigated raw milk samples, the content of fat, total protein, lactose, non-fat dry matter, total dry matter, respectively the pH values, total somatic cells count, cells/mL×10^3, and total bacteria count colony formed units, (cfu)/ mL×10^3, were determined.

The principle of the Fossomatic 7DC method for the total somatic cells is to color the cells with a fluorescent dye Dye DC, after which the cells are counted automatically (Ilea, 2019a). BactoScan FC device colors the milk bacteria with a fluorescent dye, reduces and disperses the milk components, so that the bacteria can be counted (Ilea, 2019b).

Milkoscan is a high capacity, fully automatic, mid-range infrared FTIR (Fourier Transformation Infrared Spectroscopy) analyzer and is used to determine the parameters of milk samples. The determined parameters are: fat, protein, casein, lactose, urea, dry matter, pH (Ilea, 2019c).

Statistics

The statistical analysis of the obtained data was performed by using XLSTAT software for Excel 2022 version (Addinsoft, New York, NY, USA). The variation coefficient (VC) was calculated using Equation 1 and the standard error (SE) was calculated using Equation 2.

$$VC(\%) = \frac{s}{|\bar{x}|} \cdot 100 \quad (1)$$

where s is the standard deviation and $\bar{x}$ is the mean value of the data.

$$SE = \frac{s}{\sqrt{n}} \quad (2)$$

where s is the standard deviation and n is the number of samples.

The differences among samples considered significant at $p < 0.05$ were underlined by means of the *Student t* test, and the relationships between variables were evidenced by Principal Component Analysis (PCA) with varimax rotation.

Results and discussion

Documentation regarding the technological process of Dorna Swiss cheese

The Swiss cheese factory processes 600–1000 L of milk daily, reaching approximately 14.000 L of milk per month. From a quantity of approximately 600 L of milk, 420 L is used to obtain a piece of Swiss (approximately 35–40 kg), and the remaining 180 L to obtain 4 pieces of Raclette (of 4–5 kg). By processing 1000 L of milk, 840 L is used to obtain two pieces of Swiss cheese, and the rest to obtain Raclette. The processing is traditionally done in a Copper tank (Figure 2A, B) with a capacity of 430 L, on a hob heated with wood (Figure 2C) going through the stages described below (Figures 1 and 2). The processing steps of the technological flow implemented by the factory to obtain the Dorna Swiss, are presented in Figure 1. In Figure 2, some images that capture details from the steps implemented in the processing procedure of this assortment of cheese are shown.

Processing steps for Dorna Swiss cheese production:

- Slow pasteurization of 30% of the milk quantity at 60 °C for 35 min (Figure 2C, D);
- Addition of 70% raw milk, manual mixing for normalization at 30 °C (Figure 2E);
- Proceeding with the normalization, with the extraction of the cream, so that the fat content reaches 3.2%;
- Addition of thermophilic culture of propionic bacteria and mesothermophilic culture of lactic bacteria, continuing manual homogenization (Figure 2F);
- Addition of the rennet, coagulation taking place in 30–40 minutes (Figure 2G);
- Cutting the curd by going through the steps of mixing with the sieve (from the bottom of the tank to the surface to homogenize the temperature of the entire curd) (Figure 2H), cutting it into prismatic columns (Figure 2I, J), perpendicular cutting to form cubes, shredding with the harp until it reaches the size of rice grain;
- Manual homogenization for dehydration and drying of the curd grains, for 20–30 minutes, depending on the consistency (Figure 2J);
- Stop homogenization and remove 30% of the whey (Figure 2K), following a new heating, also called scalding (Figure 2L), in which the temperature must reach 54 °C. During all this time, it is continuously homogenized, the tank is removed from the hob and the manual stirring continues, with short breaks (40–60 minutes), to dry and dehydrate the curd grains. At the same time, a manual test of the grains is done by squeezing them by hand, and if the grains stick together, the homogenization continues for complete dehydration, followed by a new evaluation, where if the grains break into pieces, it means that the process is over (Figure 2M);
- Sedimentation and removal of the remaining whey, until it reaches a few centimeters above the formed curd (Figure 2N);
- Removing the curd, and placing it into the press, where a rounded piece of approximately 35–42 kg is formed (Figure 2O, P, Q, R);
- Turning the curd for 6–7 hours (about 7–8 times), at first more often and then less often, with the time increasing with the rise of pressing force, so that the last turning is done in the evening at the end of the program and the curd should remain in the press until the next morning;
- The curd is removed from the press the next day and the edges that have extravasated after pressing are cleaned, giving them a conical shape to avoid pinching and contamination;
- Brining, at a temperature of 16 °C, for 3 days, in 26% brine;

- Whipping and placing on the shelf in the first chamber for pre-fermentation, about 14–21 days, at 14 – 160 °C and 85% humidity, during which the curd is turned every day (Figure 2S);
- Continuing maturation for about 6 weeks, in the 2nd room, at 23–25 ºC and 85% humidity;
- Airing and washing the curd pieces, with brine, 2–3 times a week, during maturation in the first and second rooms, to prevent the appearance of mold;
- Drying again, after placing the pieces of cheese on the shelf, during this time the shelves are sanitized for maturing;
- Storage of the cheese, at 10–12 °C and 80–85% humidity, for 30 days in the 3rd room, where the humidity is kept, to maintain the rind moistly and favor the release of excess gases, thus perfecting the quality of the Swiss cheese (Figure 2T);
- The total maturation time is 90 days, after which the Swiss cheese can be consumed, (Figure 2U), and if it remains in storage beyond this period, its sensory qualities increase.

The last images (Figures 2T and U) show the detailed appearance of the Dorna Swiss, with 90 days of fermentation, which is presented in the form of cylindrical pieces, with a slightly grainy side surface, with a diameter of 65–68 cm and a height between 16–17 cm.

Chemical composition and hygienic-sanitary characteristics of the milk raw material

The evolution of the chemical composition and hygienic-sanitary characteristics of the milk raw material fell within the Romanian and European standards SR2418/2008 and Romanian Government decision no. 954/2005 for milk physicochemical and microbiological characteristics (Tables 1 and 3). The comparative evolution of the compositional parameters of raw milk in the summer-winter period showed that their average and individual values presented more or less important variations.

According to the data presented in Tables 1, 3 and 5, the fat reached similar values (3.86%) in the two seasons, but with different individual oscillations (3.32–4.67% in summer and 3.25–4.63% in winter). The total protein content values were lower in summer (3.15%; variation between 2.74–3.50%) than in winter (3.32%; variation between 2.91–4.19%). Total casein values were also lower in summer (2.55%, varying between 2.23 and 2.80%) than in winter (2.68%, varying between 2.29 and 3.41%), and in the case of lactose, the decreases from the summer season were even more important (4.62%; 4.00–4.91% in summer and 4.90%; 4.25–5.67% in winter). Summer milk presented higher values compared to winter in terms of non-fat dry matter (8.95%; 7.75–10.76% in winter, and 8.54%; 7.32–8.68% in summer) and total dry matter (12.86; 11.81–15.48% in winter and 12.35%; 11.19–13.54% in summer). The pH was characterized by significant differences between seasons (6.32 in summer, 6.60 in winter). The evolution of total somatic cell count and total bacteria count, hygienic-sanitary indices with a major impact in monitoring udder health and implicitly milk, revealed low average and individual values in line with the Romanian and European standards. The standard SR2418/2008 mentions that the minimum content of fat and protein in milk must be 3.2%, while the non-fat dry mater must be at least 8.5%. The Romanian Government decision no. 954/2005 for the approval of the specific rules of hygiene for food of animal origin specifies that the total bacteria count for milk intended for the manufacture of products obtained from raw milk through a process that does not involve heat treatment must be lower that 500×10^3 cfu/mL, while the total somatic cells must be below 400×10^3 cells/mL.

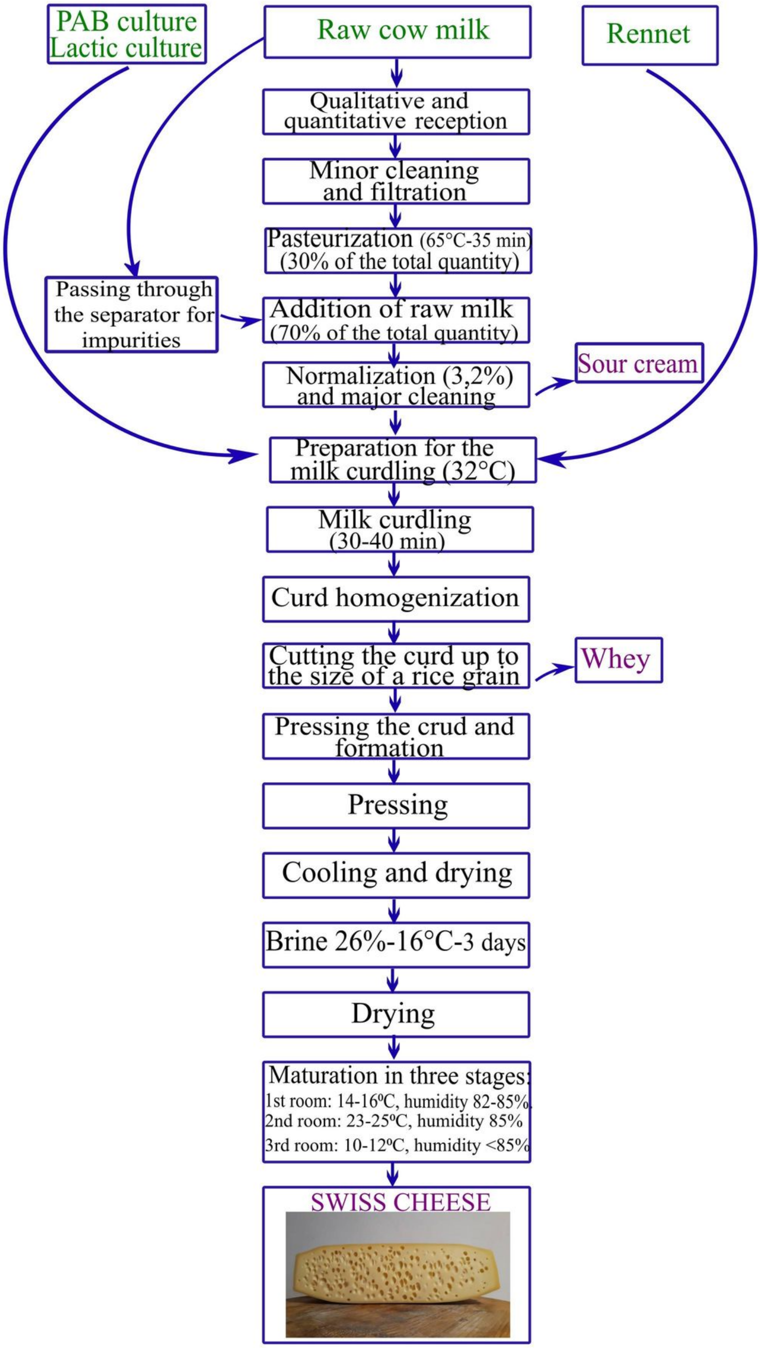

Figure 1. **Representation of the technological processing flow of Dorna Swiss cheese**

Figure 2. Representative steps from the technological processing flow, materials, and equimpents used in the manufacturingof Dorna Swiss cheese

Continue of Figure 2.
Representative steps from the technological processing flow, materials, and equimpents used in the manufacturingof Dorna Swiss cheese

q *r* *s* *t* *u*

Continue of Figure 2.
Representative steps from the technological processing flow, materials, and equipments used in the manufacturingof Dorna Swiss cheese

a, copper tank;
b, milk for pasteurization (30% of the total quantity);
c, fireplace heated with wood;
d, pasteurization at 60°c;
e, addition of 70% unpasteurized raw milk;
f, addition of propionic and lactic acid bacteria culture;
g, coagulation of milk;
h, mix of the curd;
i, cutting the curd;
j, manual homogenization;
k, elimination of 30% of the whey;
l, scalding at 54°c;
m, annual testing;
n, elimination of the remaining whey;
o, curd removing;
p, removal of the curd by using a pulley;
q, placing the curd in the press;
r, pressing;
s, refermentation room;
t, storage room;
u, swiss cheese final product

Table 1

Physico-chemical and hygienic-sanitary parameters of milk in the summer season

Sample	Fat (%)	Protein (%)	Casein (%)	Lactose (%)	Non-fat dry matter (%)	Total dry matter (%)	pH	Somatic cells count (cells/mL ×10^3)	Total bacteria count (cfu/mL ×10^3)
1	3.32	3.45	2.71	4.43	8.60	12.00	6.57	169	77
2	3.52	2.86	2.41	4.85	8.52	12.06	6.51	17	100
3	3.92	3.08	2.50	4.61	8.44	12.44	6.56	185	82
4	3.58	2.92	2.47	4.89	8.58	12.12	6.51	56	80
5	3.72	2.74	2.23	4.00	7.32	11.19	6.43	144	91
6	3.93	3.09	2.60	4.61	8.70	11.36	6.52	162	31
7	3.93	3.3	2.62	4.61	8.67	11.75	6.58	222	70
8	3.71	3.27	2.62	4.64	8.68	12.47	6.56	330	45
9	3.84	3.15	2.49	4.43	8.35	12.28	6.35	339	101
10	4.08	3.2	2.58	4.56	8.54	12.70	6.57	333	96
11	4.44	3.08	2.53	4.74	8.62	13.14	6.62	399	95
12	3.75	3.01	2.42	4.32	8.03	11.90	6.49	379	100
13	4.44	3.10	2.54	4.77	8.62	12.04	6.08	69	73
14	3.64	3.01	2.43	4.55	8.33	12.05	6.61	307	84
15	3.69	3.17	2.58	4.87	8.85	12.56	6.67	357	68
16	4.5	3.4	2.70	4.70	8.92	13.39	6.70	46	71
17	3.5	3.13	2.51	4.35	8.17	11.75	6.57	248	69
18	4.6	3.5	2.80	4.80	8.95	13.40	6.24	28	99
19	4.67	3.16	2.60	4.83	8.82	13.54	6.65	187	61
20	4.2	3.33	2.67	4.91	9.04	12.99	6.67	58	76
VC (%)	0.10	0.06	0.05	0.05	0.04	0.05	0.02	0.64	0.24
SE	0.09	0.04	0.03	0.05	0.09	0.15	0.03	28.80	4.19

VC – variation coefficient, SE – standard error of the mean.

Pearson correlation coefficients between variables in the summer season are presented in Table 2. Significant positive correlations ($p < 0.05$) were observed between casein and protein content ($r = 0.95$), between protein and non-fat dry matter ($r = 0.70$) and total dry matter ($r = 0.55$). All the chemical parameters studied were positively correlated ($0.55 < r < 0.72$, $p < 0.05$) with the total dry matter content and with the non-fat dry matter ($0.46 < r < 0.87$, $p < 0.05$). The casein content was positively correlated ($r = 0.51$, $p < 0.05$) with the lactose content of milk in the summer season.

Table 2

Pearson correlations coefficients between variables in the summer season

Variables	**Fat**	**Protein**	**Casein**	**Lactose**	**Non-fat dry matter**	**Total dry matter**	**pH**	**Somatic cells count**	**Total bacteria count**
Fat	**1**								
Protein	0.36	**1**							
Casein	0.44	**0.95**	**1**						
Lactose	0.41	0.30	**0.51**	**1**					
Non-fat dry matter	**0.46**	**0.70**	**0.85**	**0.87**	**1**				
Total dry matter	**0.72**	**0.55**	**0.60**	**0.61**	**0.67**	**1**			
pH	-0.17	0.10	0.10	0.12	0.20	0.23	**1**		
Somatic cells count	-0.21	-0.09	-0.21	-0.33	-0.24	-0.07	0.27	**1**	
Total bacteria count	0.00	-0.20	-0.32	-0.18	-0.33	0.13	-0.26	0.05	**1**
Values in bold are different from 0 with a significance level alpha = 0.05									

The first two principal components explained 62.88% of the total data variance, of which 46.42% was attributed to the first component (PC1) and 16.46% to the second one (PC2), as can be depicted in Figure 3.

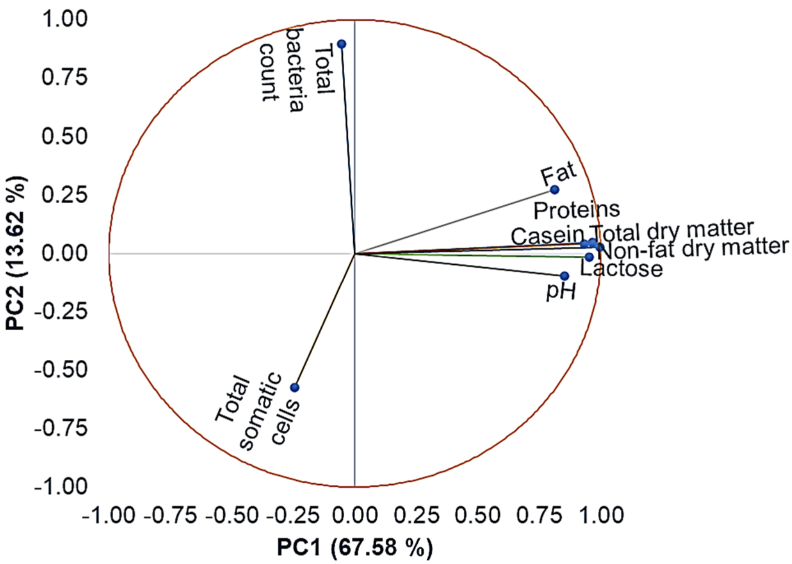

Figure 3. Principal component analysis variables plot for the summer season

The first component (PC1) was associated with the chemical components of milk – protein, casein, non-fat dry matter, total dry matter, lactose, and fat, while the second one (PC2) was associated with the microbiological and pH characteristics – total bacteria count, somatic cells count, and pH. It can be seen that an opposition occurs between the total bacteria count and pH (Figure 3).

The data registered in Tables 1, 3, and 5 show that during the summer season, the total somatic cell count presented average values of 201.75×10^3 cells/mL, with oscillations between 17×10^3 and 399×10^3 cells/mL, which exceeded the values recorded in the winter season, when the average levels were 78.45×10^3 cells/mL, with oscillations between 70×10^3 and 320×10^3 cells/mL. The total bacteria count also highlighted low and very close average levels in the two seasons, with oscillations between 31×10^3 and 101×10^3 cfu/mL in the summer period, and with oscillations between 36×10^3 and 101×10^3 cfu /mL during the winter period.

Table 3

Physico-chemical and hygienic-sanitary parameters of milk in the winter season

Sample	**Fat (%)**	**Protein (%)**	**Casein (%)**	**Lactose (%)**	**Non-fat dry matter (%)**	**Total dry matter (%)**	**pH**	**Somatic cell count (cells/mL x10^3)**	**Total bacteria count (germs/mLx10^3)**
1	3.93	3.3	2.62	4.61	8.67	11.75	6.57	113	95
2	3.28	2.91	2.29	4.25	7.75	11.18	6.52	216	93
3	3.93	3.30	2.62	4.61	8.67	11.75	6.58	139	99
4	3.25	3.06	2.44	4.57	8.27	11.67	6.56	165	101
5	4.15	3.70	2.98	5.04	9.52	13.81	6.58	125	100
6	3.95	3.13	2.54	4.85	8.70	12.82	6.59	85	100
7	3.98	3.10	2.57	4.88	8.60	12.78	6.57	103	87
8	4.07	3.08	2.50	4.76	8.56	12.80	6.56	320	100
9	3.54	3.05	2.42	4.47	8.14	11.81	6.56	299	43
10	3.85	3.48	2.83	5.26	9.55	13.51	6.66	114	75
11	3.94	3.62	2.94	5.36	9.79	13.85	6.66	163	36
12	4.10	3.64	2.91	4.90	9.32	13.70	6.60	112	100
13	3.60	2.97	2.40	4.69	8.32	11.85	6.54	164	92
14	3.45	3.17	2.57	4.82	8.68	12.27	6.59	106	64
15	3.87	3.49	2.84	5.3	9.61	13.61	6.66	159	100
16	4.05	3.43	2.77	4.95	9.13	13.33	6.59	101	100
17	4.04	3.53	2.86	5.04	9.35	13.55	6.59	78	70
18	3.84	3.09	2.53	4.99	8.83	12.82	6.63	111	100
19	4.63	4.19	3.41	5.67	10.76	15.48	6.68	189	100
20	3.84	3.09	2.53	4.99	8.83	12.82	6.63	116	98
VC (%)	0.08	0.10	0.10	0.07	0.08	0.08	0.01	0.44	0.23
SE	0.07	0.07	0.06	0.07	0.15	0.23	0.01	14.61	4.42

VC – variation coefficient, SE – standard error of the mean.

Significant positive correlations were obtained between the physico-chemical composition and hygenic-sanitary indices of the milk in the winter season (Table 4). Thus, the fat content was correlated with all the other chemical compounds content and pH ($0.54 < r < 0.85$, $p < 0.05$), similar to the protein content ($0.68 < r < 0.99$, $p < 0.05$) which showed strong correlations with the other variables, to the casein ($0.80 < r < 0.97$, $p < 0.05$), to the lactose content ($0.71 < r < 0.95$, $p < 0.05$), to the non-fat dry matter ($0.79 < r < 0.79$, $p < 0.05$) and to the total dry matter ($0.78 < r < 0.95$, $p < 0.05$). The pH variable was positively correlated with all the other studied characteristics ($0.54 < r < 0.91$, $p < 0.05$).

Table 4

Pearson correlations coefficients between variables in the winter season

Variables	**Fat**	**Protein**	**Casein**	**Lactose**	**Non-fat dry matter**	**Total dry matter**	**pH**	**Somatic cells count**	**Total bacteria count**
Fat	**1**								
Protein	**0.78**	**1**							
Casein	**0.80**	**0.99**	**1**						
Lactose	**0.71**	**0.79**	**0.86**	**1**					
Non-fat dry matter	**0.79**	**0.94**	**0.97**	**0.95**	**1**				
Total dry matter	**0.82**	**0.88**	**0.92**	**0.93**	**0.95**	**1**			
pH	**0.54**	**0.68**	**0.72**	**0.91**	**0.85**	**0.78**	**1**		
Somatic cells count	-0.17	-0.20	-0.23	-0.27	-0.26	-0.20	-0.26	**1**	
Total bacteria count	0.23	-0.01	-0.01	-0.06	-0.02	0.02	-0.11	-0.19	**1**
Values in bold are different from 0 with a significance level alpha = 0.05									

The plot of the Principal component analysis (PCA) for the variables in the winter season is shown in Figure 4. The first two components explained 81.20% of the data variation, with 67.58% being explained by the first one (PC1) and 13.62% by the second one (PC2). The physicochemical characteristics (fat, protein, casein, total dry matter, non-fat dry matter, lactose and pH) were associated with the PC1, while the hygienic-sanitary properties (total bacteria count, total somatic cells count) were associated with PC2.

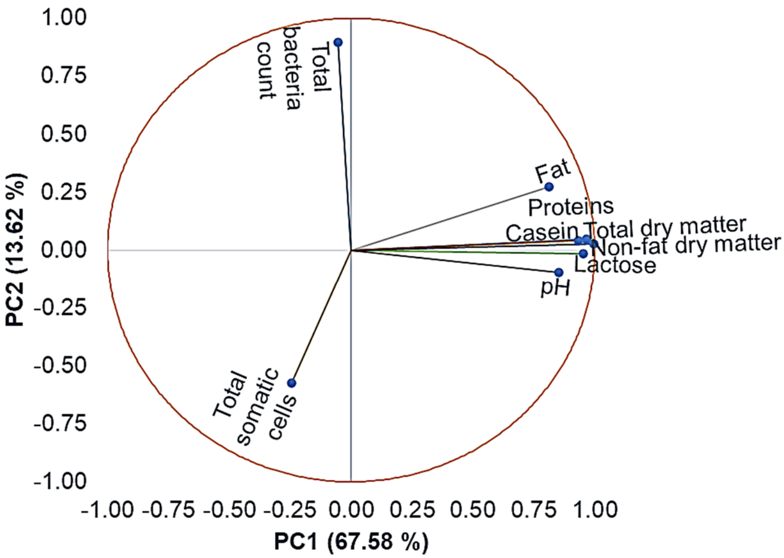

Figure 4. Principal component analysis variables plot for the winter season

Discussion

The set of positive results obtained in the physicochemical and hygienic-sanitary examinations of the milk intended for the Dorna Swiss cheese (Table 5), reveals an important concern of the farmers for its quality, of the processor for its suitability for the specific processing and of the consumer for food safety.

In recent decades, the globalization of food markets has taken a large scale and diversification, thus favoring the industry of milk and dairy products. Thus, the circulation of food products has greatly increased, at the same time intensifying the exchanges produced between the most distant regions of the globe (Silanikove et al., 2015). This globalization also represents a great challenge for processors, who must increase the quality and safety of the products sold, respectively satisfy the growing demands of consumers (Someșan et al., 2016; Svederberg, and Wendin, 2011). Current cheese production technologies ensure a wide variety of assortments, which respond to the needs and preferences of consumers. These considerations explain the classification of dairy products into: conventional products, obtained according to conventional recipes and technologies; traditional products, processed in a certain geographical area, based on traditional recipes; and ecological products, obtained from raw materials generated by ecological agriculture (De Pasquale et al., 2014; Ercolini et al., 2003). For all these products, a common characteristic is the quality of milk as a raw material, which must reach a high degree of compliance with regard to the compositional and sanitary parameters.

The analysis of the data obtained during the investigation of the seasonal evolution of the physicochemical parameters of milk, the raw material for Swiss cheese processing, revealed a slightly lower concentration of some milk parameters in the summer season compared to the winter. Lower levels of total dry matter (12.35 vs. 12.86%), total protein (3.15 vs. 3.32%), lactose (4.62 vs. 4.90%), and non-fat dry matter (8.54 vs. 8.95%) were obtained in summer compared to winter. The changes in hygienic and sanitary parameters values were marked by important increases in total somatic cell count in the summer season (201.75 × ×10^3 cells/mL), compared to those recorded in the winter season (78.45×10^3 cells/mL) and very close levels values of total bacteria count (81.7 and 87.65×10^3 cfu/mL, respectively). Similar results were reported by other researchers in the field (Cziszter et al., 2012; Dobranić et al., 2008).

Table 5

Average values and variations of the physicochemical and hygienic-sanitary characteristics of the milk used in the processing of Dorna Swiss cheese

Parameter	Summer		Winter	
	Mean value	Variations	Mean value	Variations
Fat (%)	3.95±0.40 ^{a}	3.32–4.67	3.86±0.32 ^{a}	3.25–4.63
Protein (%)	3.15±0.19 ^{b}	2.74–3.50	3.32±0.32 ^{a}	2.91–4.19
Casein (%)	2.55±0.13 ^{a}	2.23–2.80	2.68±0.26 ^{a}	2.29–3.41
Lactose (%)	4.62±0.23 ^{b}	4.00–4.91	4.90±0.33 ^{a}	4.25–5.67
Non-fat dry matter (%)	8.54±0.38 ^{b}	7.32–9.04	8.95±0.69 ^{a}	7.75–10.76
Total dry matter (%)	11.98±0.67 ^{b}	11.19–13.54	12.86±1.03 ^{a}	11.18–15.48
pH	6.37±0.15 ^{b}	6.08–6.70	6.60±0.04 ^{a}	6.52–6.68
Somatic cells count (cells/mLx×10^3)	201.75±12.87 ^{a}	17–399	78.45±65.34 ^{b}	78–320
Total bacteria count (cfu/mL×10^3)	81.7±18.75 ^{a}	31–101	87.65±19.77 ^{b}	36–101

^{a,b} – different letters in the same row indicate significant differences between means (p < 0.05).

Soil-plant-animal transfer of nutrients depends on the quality of the soil and its rich mineralization, and the great floristic diversity of pastures and mountain meadows will lead to a milk rich in biologically active substances (terpenes, carotenoids, lactic bacteria, propionic and compounds high-quality volatiles) (Kilcawley et al., 2018; O'Callaghan, et al., 2016; Necula, et al., 2021; Nozière et al. 2006). The propionic bacteria existing in raw milk play an essential role in the production of Emmental cheese, because the fermentation of propionic acid during maturation gives a specific flavor to this type of cheese and causes the formation of holes in a controlled manner (Fröhlich-Wyder et al., 2017).

Among the producers of Dorna Swiss cheese, the studied factory is currently the only one that processes Swiss cheese in copper tanks and vats, similar to those used to obtain the traditional Swiss Emmental. According to the literature, the copper in these tanks has the role of inhibiting the uncontrolled generation of lactic and propionic acid, thus slowing down the explosive propionic fermentation. It also inhibits the sporulated germination of *C. Tyrbutyricum* and implicitly the late swelling of the curd during maturation (Rodriguez and Alatossava 2010; Rodriguez et al 2011). The copper in these tanks forms complexes with the sulfurous compounds resulting from amino acid catabolism, having a positive effect on the production of cheese flavor (Sieber, et al. 2006). Another particularity is the formation of the well-known holes that appear during maturation when propionic bacteria consume lactic acid and release CO_2, and the bubbles formed give holes (Chen et al., 2009; Fröhlich-Wyder et al., 2017; Ji et al., 2004; Rehn et al., 2011).

From an organoleptic point of view, the quality of the Swiss cheese in terms of color, fermentation holes aspect, consistency, smell, and taste is appreciated (Necula and Babii, 2012). The curst must be smooth, elastic, thick (about 1 cm), golden – yellow to reddish – yellow in color, and slightly greasy in fully matured cheese. Golden – yellow paste, lighter in winter and more intense in summer, with a smooth, glossy inner surface and fermentation meshes, 1–2 cm, evenly distributed. The consistency is elastic, fine, not crumbly. The smell and taste are slightly sweet, and the aroma is similar to green walnut core. Salt also influences the organoleptic properties of this cheese assortment, contributing to ensuring the specific flavor and its preservation (Düsterhöft et al., 2017; Guinee and Fox, 2017). Strict compliance with the temperature and humidity conditions in the maturation and storage areas has a major role in perfecting the biologically active and sensory qualities of the Emmental type cheese.

Conclusions

Dorna Swiss cheese is part of the large brand of "Emmental" type cheeses, or as is also called "Swiss type" cheese. This type of cheese is made in Romania in Dorna geographic area. All traditional Emmental hard cheeses made from raw milk enjoy an excellent food safety record from a veterinary health point of view as those made from fully pasteurized milk, due to the fact that pathogens are annihilated by the initial culture of propionic bacteria, the long period of curd scalding at 54ºC and the long maturation period of three months. The main characteristic of Swiss cheese is given by its unique texture, taste, aroma, and the well-known image of the holes that make it different from any other type of cheese.

The factory studied is the only one in the Dorna area that still uses the traditional Swiss processing procedure, in copper tanks, on a hob heated with wood, and from milk obtained predominantly from Pinzgau cows, raised in mountain conditions.

The evolution of the compositional parameters of raw milk in the summer-winter period, revealed no significant differences ($p < 0.05$) in fat content, lower values in summer than in winter for the total protein and casein, and significant decreases in lactose in the summer season. Higher values of non-fat dry matter and total dry matter of milk were obtained in winter compared to the summer season.

The evolution of the hygienic-sanitary indices revealed the low values, in agreement with the Romanina and European standards. The total somatic cell count was slightly higher in the summer season compared to the winter, while the total bacteria count showed low and very close levels in the two seasons.

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