The Influence of Season on the Cow Milk Quantity, Quality and Hygiene

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Abstract

The purpose of this study was to evaluate the effects of season of collection on the quantity, quality and hygienic properties of the raw milk delivered from one dairy farm. The studied traits were: bulk tank milk yield, chemical composition (fat, protein, lactose, and total solids), freezing point, density, total bacteria count, coliform bacteria count and somatic cell count, during years 2010 and 2011. A total of 727 samples were drawn and analysed in two laboratories, using the standard methods. Average milk production per day per head in the farm was 13.58 kg, obtained from 252 cows. Year of collection had a significant effect on the bulk tank raw milk yield, quality and hygiene, except for freezing point and total bacteria count. The raw milk yield and chemical composition improved ($p<0.05$) from year 2010 to year 2011, as well as the hygienic quality. Season of collection had a significant ($p<0.05$) influence on the milk yield and chemical composition, the highest milk yield with the lowest concentration being obtained during summer, while the lowest milk yield with the highest chemical composition was obtained in winter. Physical properties of the raw milk were less affected by the season of collection, with the lowest freezing point in the winter and the highest density in the autumn. The highest somatic cell count and coliform bacteria count was obtained during the spring and the lowest total bacteria count was obtained in winter season. There was a significant ($p<0.05$) interaction between year and season of production for all raw milk traits.

Keywords: bacteria count, chemical composition, coliform count, density, freezing point, milk yield, raw cow milk, somatic cell count

1. Introduction

Understanding the variability in milk yield, milk composition, physical and hygienic parameters of milk is important when making management decisions and in milk-recording programs. [1,2].
The composition and functional properties of cow's milk are of considerable importance to the dairy farmer, manufacturer, and consumer. Broadly, there are 3 options for altering the composition and/or functional properties of milk: cow nutrition and management, cow genetics, and dairy manufacturing technologies [3]. The concentration and composition of protein in milk are largely unresponsive to variation in nutrition and management.
Somatic cell count is usually used to detect udder infection, especially the sub-clinical mastitis [1]. The total bacteria count shows how the milk was harvested, manipulated and stored before reaching the milk processing plant.
Coliform bacteria are a commonly used bacterial indicator of sanitary quality of foods and water. They are defined as rod-shaped Gram-negative non-spore forming bacteria which can ferment lactose with the production of acid and gas when incubated at 35-37°C. Coliforms can be found in the aquatic environment, in soil and on vegetation; they are universally present in large numbers in the faeces of warm-blooded animals. While

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coliforms are themselves not normally causes of serious illness, they are easy to culture and their presence is used to indicate that other pathogenic organisms of faecal origin may be present, including bacteria, viruses, or protozoa and many multicellular parasites [4].
The freezing point of milk depends upon the concentration of water-soluble components. As milk is more diluted, the freezing point will raise closer to zero. The current official freezing point limit (-0.525 degrees Horvet or -0.505 degrees C) was designed for whole-herd, bulk-tank samples or processed milk samples, and not for samples from individual cows or individual quarters. The value of -0.525 degrees Horvet is considered the upper limit which statistically is suppose to be a cut-off for most, but not absolutely all, samples to be considered "water-free". However, freezing point of milk as a regulatory standard is really only valid for milk pooled form many cows (bulk tank milk). Many factors may affect freezing point of milk from individual cows. High producing cows might be expected to have higher freezing points than lower producing cows. Diet, and how and when the diet is fed relative to collecting the milk sample, also may affect freezing point from individual cows. Little work has been done in recent years to define freezing point on milk from modern high producing dairy cattle [5].
Freezing point belongs to the key properties of milk. Many factors affect it. From among the main milk constituents, lactose and chlorides mostly influence freezing point. If combined, they account for 75–80% of the final freezing point. The remaining 20–25% of the freezing point value is affected by other milk constituents – calcium, magnesium, lactates, phosphates, citrates, urea etc. [6] The freezing point of milk is determined by the proportion of milk constituents in a true solution and whose content in milk is affected by a number of factors: e.g. breed, stage and number of lactation, occurrence of subclinical mastitis, nutritional deficiencies, water intake, weather conditions, thermal stress, seasonal influences, presence of CO2 in milk. It was shown that minor details of analysis have to be considered, otherwise freezing point data cannot be compared [7].
The aim of the present study was to study the influence of season on the raw cow milk yield, chemical composition and hygiene.

2. Materials and methods

Researches were carried out on the dairy farm of the Research and Development Station for Bovine Arad, where the main breed was Romanian Spotted of Fleckvieh type.
The milk yield collected in the bulk tank and the number of cows milked was recorded daily, during two consecutive years 2010 and 2011. Also, a milk sample was drawn every day from the milk bulk tank and analysed for chemical composition, density, freezing point, and microbiological load. Chemical composition (fat, protein, lactose, totals solids) as well as the freezing point were carried out by using the FOSS Milkoscan Minor™. Density of milk was determined using the thermo-lacto-densimeter. Somatic cell count in milk was determined using either the FOSS Fossomatic Mino™ or the classical smear reading following the SR EN ISO 13366-1/2010 standard. Total bacteria count was performed using the classical method, following the SR EN ISO 4833/2003 standard. Coliform bacteria count in milk was determined following the SR ISO 554111191 and SR ISO 5541/2/94 standards. The average milk production per cow and per day was obtained by dividing the total milk in bulk tank to the number of cows milked in that day.
An analysis of variance model was used in order to test the influence of year (2010 and 2011) and season of production (winter, spring, summer, and autumn) on these raw milk traits.

3. Results and discussion

Generally, there was found a significant influence of the year of study on the milk yield, quality and hygiene.
Table 1 presents the averages for raw milk traits from the bulk tank in the two consecutive years of the study. The average number of cows milked in each year was 252 heads, varying from 241 to 258 cows in year 2010 and from 243 to 261 in year 2011. In year 2010 3346.3 kg milk was collected and sold, on average, daily from the farm, meaning a mean production of 13.29 kg per day per cow, while in 2011 the production was significantly higher ($p<0.001$) by 136.1 kg milk per day and 0.57 kg milk per day and per head, respectively. The minimum milk yield sold daily

from the farm was 2600 kg milk in year 2010 and 2450 kg in year 2011, while the maximum milk yield produced was 4340 kg and 4540, respectively.

Raw milk chemical composition was significantly different (p<0.001) according to the collection year (Table 1). Thus in year 2010 the milk from bulk tank had, on average, 4.089% fat, 3.355% proteins, 4.662% lactose and 12.875% total solids. The milk collected in year 2011 had more fat (4.176%), more proteins (3.367%), less lactose (4.565%) and more total solids (12.976%).

The freezing point was not significantly different between the two years of study, though in year 2010 it was slightly lower than in year 2011 (-0.523 vs. -0.525°C, respectively). Average value of the milk density was significantly higher in year 2011 than in year 2010, 1.03 and 1.0299, respectively (p<0.001). Results found in our study were lower than those published in year 2010 [8] for Romanian Spotted breed, which was the main breed in our farm, of -0.547°C, ranging from -0.539°C to -0.548°C.

The average somatic cell count was below the maximum level of 400000 per ml, in both years. In year 2010 somatic cell count was higher than in year 2011 (137695.1 and 226350.1, respectively), the difference of 11345 cells/ml reaching the statistical significance level (p<0.001).

The average total bacteria count was less than 50000 cfu/ml in both years, and the difference between the two study years was not significant (210.9 cfu/ml, p>0.05). The minimum level of total bacteria count was 25000 cfu/ml in year 2010 and 25000 cfu/ml in year 2011. The maximum level determined in the bulk tank milk did not exceeded the maximum level admitted (100000 cfu/ml), being 93000 cfu/ml in year 2010 and 94000 cfu/ml in year 2011.

Coliform bacteria count was slightly higher in year 2010 than in year 2011, and the difference of 0.12 cfu/ml reached the significance level (p<0.001). Coliform bacteria count ranged from 0.3 to 1.7 cfu/ml in year 2010 and from 0.1 to 6 cfu/ml in year 2011.

As a conclusion, we can observe that from year 2010 to year 2011 the milk production and quality increased, as well as the hygienic properties of the milk from the bulk tank, providing high-quality raw milk.

Table 1. Means and dispersion indices for raw milk traits according to year of collection

Trait	2010	2011	Difference and significance
n	364	363	-
No. of cows milked	252	252	-
Total milk collected daily (kg)	3346.3±18.75	3482.4±27.38	136.1***
Milk production per cow per day (kg)	13.29±0.0749	13.86±0.1119	0.57***
Fat percentage (%)	4.089±0.0123	4.176±0.0149	0.087***
Protein percentage (%)	3.355±0.0038	3.367±0.0032	0.012***
Lactose percentage (%)	4.662±0.0047	4.565±0.0044	-0.097***
Total solids (%)	12.875±0.0127	12.976±0.0152	0.101***
Freezing point (°C)	-0.523±0.00129	-0.525±0.00006	0.002^{ns}
Density (g/cm^3)	1.0299±0.000013	1.0300±0.00001	0.0001***
Somatic cell count (cells/ml)	237695.1±1887.59	226350.1±1860.59	-11345***
Total bacteria count (cfu/ml)	49458.8±766.59	49247.9±819.96	-210.9^{ns}
Coliform bacteria count (cfu/ml)	0.857±0.2595	0.737±0.5045	-0.120***

The season of production had a significant effect (p<0.005) on the milk yield, milk chemical composition and hygiene, and less effect on the physical properties of the milk.

The influence of season on the raw milk yield is presented in Table 2. The highest daily milk production was obtained during the summer, 3727.9 kg, followed by autumn, 3657.3 kg and by spring, 3254.4 kg, while the lowest average daily milk production was obtained in winter, 3016.6 kg. In the summer the daily milk production sold from the farm was ranging from 2980 kg to 4445 kg. The lowest variability of bulk tank milk yield was observed during the winter (from 2450 kg to 3655) and the highest during the autumn (from 2720 to 4540 kg).

Due to the fact the average number of cows milked was similar in each season, the average milk production per cow and per day was the highest in summer (14.83 kg), and the lowest in winter (11.90 kg). This seasonal distribution of the milk yield is due to the milk secretion stimulation by the green fodder, which is fed to cows during the warm season of the year, from April until October. The lowest milk yield per cow per day was produced during the winter time (9.61 kg), while the highest production was obtained during the autumn (18.2 kg). The highest variability for this trait was observed in autumn season.

Table 2. Means and dispersion indices for raw milk yield according to the season of collection

Season	n	No. of cows milked	Total milk collected daily (kg)	Milk production per cow per day (kg)
Winter	180	254	3016.6±17.17	11.90±0.086
Spring	184	251	3254.4±26.73	12.96±0.102
Summer	181	251	3727.9±28.31	14.83±0.109
Autumn	182	250	3657.3±28.59	14.61±0.112
Differences and Significance				
Winter-Spring			-237.8***	-1.06***
Winter-Summer			-711.3***	-2.93***
Winter-Autumn			-640.7***	-2.71***
Spring-Summer			-473.5***	-1.87***
Spring-Autumn			-402.9***	-1.65***
Summer-Autumn			70.6*	0.22^{ns}

Table 3. Means and dispersion indices for raw milk chemical components according to the season of collection

Season	n	No. of cows milked	Fat (%)	Protein (%)	Lactose (%)	Total solids (%)
Winter	180	254	4.44±0.0068	3.41±0.0033	4.58±0.0082	13.21±0.0116
Spring	184	251	4.15±0.0157	3.34±0.0038	4.62±0.0068	12.93±0.0173
Summer	181	251	3.89±0.0058	3.30±0.0035	4.64±0.0063	12.67±0.0069
Autumn	182	250	4.05±0.0179	3.39±0.0042	4.61±0.0073	12.89±0.0176
Differences and Significance						
Winter-Spring			0.29***	0.07***	-0.04***	0.28***
Winter-Summer			0.55***	0.11***	-0.06***	0.54***
Winter-Autumn			0.39***	0.02***	-0.03***	0.32***
Spring-Summer			0.26***	0.04***	-0.02**	0.26***
Spring-Autumn			0.10***	-0.05***	-0.01^{ns}	0.04*
Summer-Autumn			-0.16***	-0.09***	0.03***	-0.22***

Differences between seasons for total milk yield produced per day and average milk yield per cows per day were statistically significant ($p<0.001$), except for the difference between summer and autumn daily milk production per cow ($p>0.05$).

Seasonal distribution of the milk chemical composition of the raw milk from the bulk tank is presented in Table 3. As opposite to the milk yield, the bulk tank milk chemical composition was the lowest in summer (3.89% fat, 3.30% protein, 4.64% lactose and 12.67% total solids) and the highest in winter (4.44% fat, 3.41% protein, 4.58% lactose and 13.21% total solids), with intermediate values in spring and autumn.

The highest milk fat percentage was found in winter (4.6%), while in the summer the maximum value that was observed was 4.0%, value that was representing also the minimum value during the winter. The minimum value for fat percentage was observed in autumn, 3.6%. Protein percentage ranged from a minimum value of 3.2% observed in spring, summer and autumn and the maximum value of 3.5% observed in winter and autumn. The minimum value for lactose percentage was 4.4% and was observed in all seasons, while the maximum value of 5.0% was obtained in winter. Total solids percentage was as low as 12.3% in winter and as high as 13.6% in autumn. The lowest variability for total solids in the bulk tank raw milk was observed during the summer, ranging from 12.5 % to 13.0%.

Season has greatly affected the chemical composition of the bulk tank milk, the differences between seasons for all the traits being statistically significant (p<0.05), except for the difference for lactose percentage between spring and autumn (p>0.05).This results are consistent with those presented by other scientists [9,10], showing that the milk composition was lower in summer than in winter.

Physical properties of the raw bulk tank milk collected daily in the farm, from season to season, are presented in Table 4. The freezing point of the milk varied within a small range from one season to another. The highest average for freezing point was observed during summer, -0.521°C, while during the winter was obtained the lowest value for this trait, -0.526°C. Generally, the season did not had a significant influence on the freezing point of the milk (p>0.05), except for the difference between the summer and winter, which reached the significance level (0.005°C, p <0.05). It is, also, to be observed that the average freezing point in each season did not increased over the maximum limit accepted by the standards [11], -0515°C. This means that the milk in the bulk tank was not adulterated by adding water. Other authors [12] found that the freezing point of milk was influenced by breed, successive lactations, lactation stage and the geographic region. In milk with a high urea concentration (over 300 mg/L), the increased apparent protein level caused a decrease in the milk freezing point values. The combined influence of geographic region and production season showed significant interactions for daily milk yield and total solids content and the milk freezing point. Studying freezing point of goat milk other authors [6] found that this trait had higher values in the spring months and a drop at the end of lactation. Also, the freezing point corresponded to the non-fat solids content of the milk.

Density of the bulk tank milk was ranging between the normal limits from season to season (Table 4). The highest density of milk was recorded in autumn, 1.030, while the lowest was observed in spring, 1.02994. Differences among seasons were small and non significant (p>0.05), except for those between autumn on one hand and spring and summer on the other hand (0.00006, p<0.01 and 0.00004, p<0.05, respectively).

We could state that the freezing point and the density of milk from the bulk tank were not significantly influenced by the season of collection.

Table 4. Means and dispersion indices for raw milk physical properties to the season of collection

Season	n	No. of cows milked	Freezing point (°C)	Density (g/cm^3)
Winter	180	254	-0.526±0.000078	1.02997±0.000013
Spring	184	251	-0524±0.000069	1.02994±0.000018
Summer	181	251	-0.521±0.002602	1.02996±0.000015
Autumn	182	250	-0.525±0.000073	1.03000±0.000005
Differences and Significance				
Winter-Spring			-0.002^{ns}	0.00003^{ns}
Winter-Summer			-0.005*	0.00001^{ns}
Winter-Autumn			-0.001^{ns}	-0.00003^{ns}
Spring-Summer			-0.003^{ns}	-0.00002^{ns}
Spring-Autumn			0.001^{ns}	-0.00006**
Summer-Autumn			0.004^{ns}	-0.00004*

Table 5 presents the averages for hygienic properties of the raw bulk tank milk collected in the farm during the study period, according to the season. The highest average for somatic cell count was observed in spring, 238858.7 cells/ml, while the lowest was observed in summer, 228221.0 cells/ml. From season to season, the daily variation of the somatic cell count in milk was higher in winter, from 95000 to 361000 cells/ml and lower in summer, from 167000 to 342000 cells/ml. This variation form season to season of the somatic cell count showed that in all seasons the milk was graded as class A milk [11] because this trait was never higher than the maximum admitted limit. The spring time average for somatic cell count was significantly higher compared to other seasons (p<0.05), while the differences among the other seasons did not reached the statistical significance (p>0.05).In other work, the authors found that somatic cell count in the milk obtained from individual cows was significantly higher in autumn than in winter calving cows [13]. Also, a significant interaction was found between season of calving and parity of cows [14]. A work on the raw milk from Western Romania [8] showed that the somatic cell count was the highest in summer and autumn, exceeding 500000 cells/ml, while the lowest was in winter and spring.

Table 5. Means and dispersion indices for raw milk hygienic properties according to the season of collection

Season	n	No. of cows milked	Somatic cell count (cells/ml)	Total bacteria count (cfu/ml)	Coliform bacteria count (cfu/ml)
Winter	180	254	230427.8±3004.08	46316.7±1053.72	0.750±0.0376
Spring	184	251	238858.7±2706.86	49364.1±1020.41	0.900±0.0351
Summer	181	251	228221.0±2280.51	51375.7±1239.30	0.762±0.0203
Autumn	182	250	230500.5±2642.68	50335.2±1136.57	0.775±0.0220
Differences and Significance					
Winter-Spring			-8430.9*	-3047.4*	-0.150***
Winter-Summer			2206.8^{ns}	-5059.0**	-0.012^{ns}
Winter-Autumn			-72.7^{ns}	-4018.5*	-0.025^{ns}
Spring-Summer			10637.7**	-2011.6^{ns}	0.138***
Spring-Autumn			8358.2*	-971.1^{ns}	0.125**
Summer-Autumn			-2279.5^{ns}	1040.5^{ns}	-0.013^{ns}

Average for total bacteria count in bulk tank milk was within the accepted limits in all season (Table 5). During the winter season the average total bacteria count was significantly lower compared with the other season; 46316.7 cfu/ml vs. 49364.1 cfu/ml in spring ($p<0.05$), 51375.7 cfu in summer ($p<0.01$) and 50335.2 cfu/ml in autumn ($p<0.05$). In the summer time was observed the highest daily variation of this trait, from 21000 cfu/ml to 94000 cfu/ml. The maximum admitted level of 100000 cfu/ml was not observed in any season, grading all the milk produced in the farm during the study period in class A, from this point of view [11]. In year 2004, out of 14 dairy farms from the Western Romania, only 5 farms were producing raw milk complying with the standards for total bacteria count, and only 8 farms produced raw milk within the accepted limits for somatic cell count [15].

Coliform bacteria count, was on average, 0.750 cfu/ml in winter, 0.900 cfu/ml in spring, 0.762 cfu/ml in summer, and 0.775 cfu/ml in autumn. The higher value of this trait in spring was significantly different ($p<0.01$) compared to the value found during the other seasons. The averages for coliform bacteria count in all seasons complied with the maximum admitted levels [11].

From data presented in Table 5 we could state that the lowest value for total bacteria count in bulk tank milk is found in winter, while in spring the somatic cell count and coliform bacteria count were higher. This mean that cows have the highest susceptibility for new intra-mammary infection during the spring time, and the bacterial stress is the lowest during the winter. Studying the lactation curve for milk yield, chemical composition and somatic cell count, the same authors [16] found that calving season had a significant effect on the shape of the lactation curve for these traits, summer calving cows having a flatter lactation curves for milk yield and composition, while for somatic cell count the flattest lactation curve was obtained in winter.

Year and season of study interacted in their effect on the milk production indices. There were significant interaction ($p<0.05$) between the two factors on the milk yield, milk chemical composition, somatic cell count and coliform bacteria count. There was no interaction between year and season for physical properties of the milk (freezing point and density) and total bacteria count.

The interaction between year and season for total milk yield produced daily in the farm is presented in Figure 1.The milk production followed different patterns in each year of study. In year 2010, total milk production steadily increased from winter to spring, summer and autumn, while in year 2011 the highest milk production was produced in summer, followed by autumn, spring and winter. The difference between years was significant only for summer season (3445.71 kg in 2010 vs. 4013.38 kg in 2011kg, $p<0.001$).

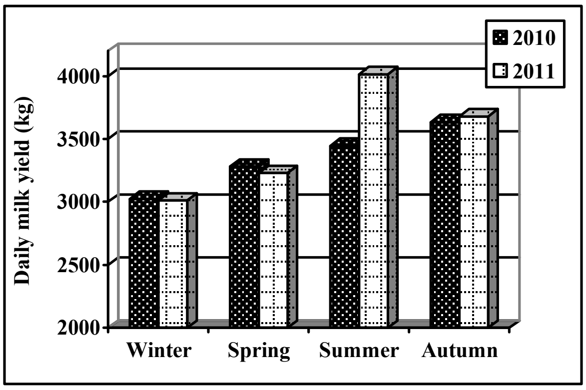

Figure 1. Seasonal evolution of the total daily milk yield for the two years of study (year x season interaction)

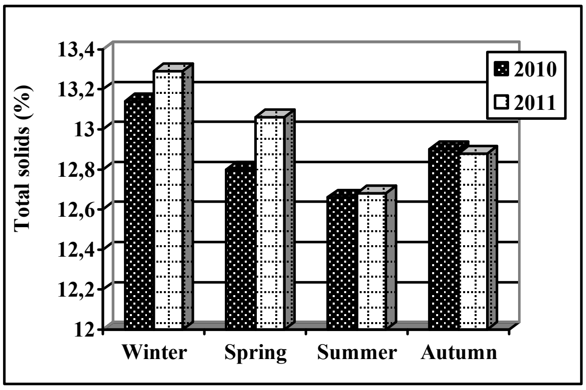

Figure 2. Seasonal evolution of the total solids in milk for the two years of study (year x season interaction)

There was, also, a significant interaction between year and season for all chemical constituents of the milk. For exemplification we show in Figure 2 the interaction between the two factors for total solids in milk. Even though the pattern of total solids content was similar between the two years from season to season, only differences for winter (13.14% in 2010 vs. 13.29% in 2011) and spring (12.8% in 2010 vs. 13.06 in 2011) were statistically significant ($p<0.001$). We can say that the total solids content of milk was the lowest in summer and then increased in autumn, irrespective of the year (see Table 3).

The season by year interaction on milk somatic cell count and coliform bacteria count of the raw milk is presented in Figure 3. These two hygienic characteristics of the milk had different patterns for each year from season to season.

Somatic cell count was similar in winter for both study years (228866.7 in 2010 and 231988.9 in 2011, $p>0.05$), while in year 2010 this trait was significantly higher than in year 2011 for spring (245413.0 vs. 232304.3 cells/ml, $p<0.05$), summer (236296.7 vs. 220055.6 cell/ml, $p<0.01$) and autumn (240022.0 vs. 220979.1$p<0.001$) seasons.

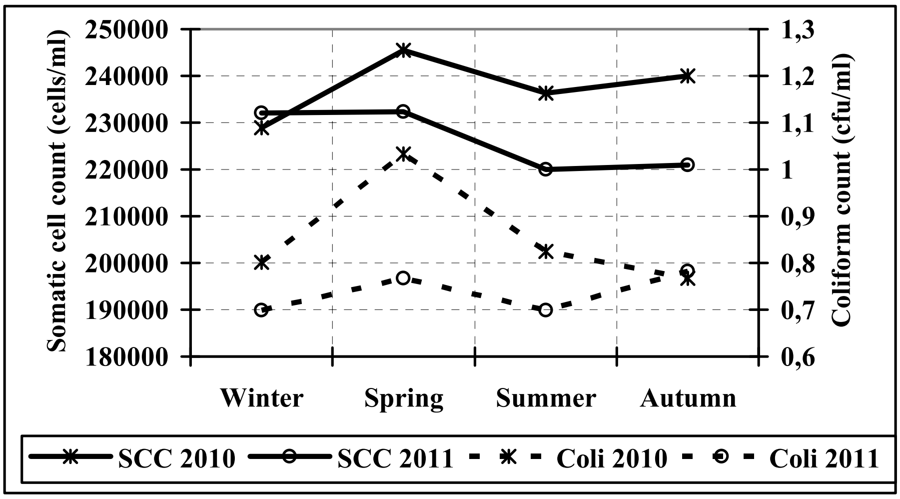

Figure 3. Seasonal evolution of the somatic cell count and coliform bacteria count in milk for the two years of study (year x season interaction)

For coliform bacteria count, there was an opposite interaction of year with season. Thus, in winter (0.802 cfu/ml in 2010 and 0.698 cfu/ml in 2011) and autumn (0.767 cfu/ml in 2010 and 0.782 cfu/ml in 2011), the differences between years of study was not statistically significant ($p>0.05$). In spring (1.032 vs. 0.767 cfu/ml) and summer (0.824 vs. 0.699 cfu/ml) the coliform bacteria count was significantly higher in year 2010 compared to year 2011.

4. Conclusions

Year of collection had a significant effect on the bulk tank raw milk yield, quality and hygiene, except for freezing point and total bacteria count. The raw milk yield and chemical composition improved from one year to another, as well as the hygienic quality obtaining a high-quality, class A milk.

Season of collection had a significant influence on the milk yield and chemical composition, the highest milk yield with the lowest concentration being obtained during summer season, while the lowest milk yield with the highest chemical composition was obtained in winter.

Physical properties of the raw milk were less affected by the season of collection, with the lowest freezing point in the winter and the highest density in the autumn.

The highest somatic cell count and coliform bacteria count was obtained during the spring and the lowest total bacteria count was obtained in winter season.

There was a significant interaction between year and season of production for all raw milk traits.

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