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VARIABILITY AND CORRELATION BETWEEN BASIC QUALITY PARAMETERS OF RAW COW MILK

N. Memiši[1], V. Bogdanović[2], Z. Tomić[3], A. Kasalica[4], M. Žujović[3], N. Stanišić[3], N. Delić[3]

[1]AD Mlekara, Tolminska 10, Subotica, Republic of Serbia
[2]Faculty of Agriculture, Belgrade, Republic of Serbia
[3]Institute for Animal Husbandry, Autoput 16, 11080, Belgrade-Zemun, Republic of Serbia
[4]Dairy Institute, Autoput 3, Belgrade, Republic of Serbia
Corresponding author: memisin@mlekara.rs
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Abstract: In this paper the results of the analysis of the milk somatic cell count are presented, as well as correlation between the somatic cell count and content of certain chemical parameters in milk (milk proteins, fat, lactose and dry matter without fat) determined in collective samples of milk obtained from cows reared in intensive rearing system, during two production years. The research was carried out by control of collective milk samples from cows reared on family holdings. Somatic cell count, as well as the chemical quality of milk, were controlled daily in the laboratory for raw milk in dairy plant AD "Mlekara" – Subotica using the apparatus CombiFoss 6200 FC. In this investigation, statistically significant correlation ($P<0,001$) between all observed milk parameters was determined. Positive, weak and statistically highly significant correlation between the content of milk fat and proteins in milk and somatic cell count was established. It was also established that the variability of chemical parameters of milk and somatic cell count is also under the influence of different factors, such as: month of control, year of the research and farm.

Key words: cows, somatic cell, composition of milk, correlation

Introduction

Somatic cell count in milk is indicator of udder health and frequency of incidence of clinical and subclinical mastitis in herd of dairy cows. Monitoring and determination of the somatic cell count in milk is very important factor in evaluation of milk quality, followed by the chemical composition of milk (milk fat and protein) and total plate count, and forming of the price of milk. Also, somatic cell count in milk can be important indicator in programs for monitoring of the mastitis. Increased somatic cell count is associated with decrease in quantity of

milk and changes in the composition of milk which can affect its suitability for further processing. Inflammatory process in the mammary gland, occurring as a consequence of the effect of microorganisms, toxins and tissue damages/injuries, leads to changes in the milk secretion, which consequently results in quantitative and qualitative changes in the milk *(Heeschen, 1995)*. These changes relate mainly to the increase of somatic cell count, increase of the content of milk serum proteins, decrease in secretion of different milk components (casein, fat, lactose) and of quantity of milk. Also, these changes lead to reduced thermo-stability, longer coagulation time and reduced viability/sustainability of milk. Based on the above, it can be concluded with certainty that increased somatic cell count in milk influences its suitability for processing *(Auldist and Hubble, 1998)*.

Increased somatic cell count (over 400.000) is penalized by reduction of factors which influence the price of raw milk. Somatic cell count in milk varies as the result of the effect of many genetic and environment factors. In addition to its impact on the purchase price of milk, somatic cell count is also important in regard to production of milk in lactation. So, *Rudolphi (2004)* states that geometrical increase from 50.000 to 100.000 of somatic cells/ml decreases the production of milk/milk yield by 1,2 % in the first and 3,6 % in the third and subsequent lactations. Increase of somatic cell count from 50.000 to 800.000 leads to decrease in milk production/milk yield by 6,3 % in the first and 9,6 % in the third and subsequent lactations. According to *Schallenberger (2002)* as the result of such udder health disorder, losses in milk production of even 1300 kg of milk per lactation can occur, which affect the profitability of the production in the amount of 665 euros per diseased animal.

The fastest way to reduce the somatic cell count in collective milk from one herd is to identify the dairy cattle with impaired secretion of milk and take measures to remove the causes that lead to this situation, which is achieved by measures of prophylaxis and treatment. Objective of this study was to analyse the variability and correlation between basic quality parameters of raw cow milk produced on family holdings, and to determine potential effect of major non-genetic sources of variability on mentioned traits.

Materials and Methods

Data obtained in regular controls of the collective milk samples of Holstein-Friesian dairy cows from family holdings in Vojvodina with intensive rearing system, during two production years, was used in this study. During the first production year 5550 milk samples were analysed, and in the second 11478 milk samples. Control included 206 family dairy farms where in total over 3000 dairy cattle was reared, and from which raw milk was purchased daily. Summary of milk samples in lactofreezers from aeach farm on somatic cells count, as well as the chemical composition of milk (milk fat, proteins, lactose and fat free dry matter) were controlled daily in the Laboratory for raw milk of the dairy plant AD

"Mlekara" – Subotica using apparatus CombiFoss 6200 FC. Determination of somatic cells count was done according to the method described in *ISO 13366-2 (2006)* and chemical composition of milk according to *ISO 9622 (1999)*. Somatic cell count is expressed as the arithmetic mean value.

Once a month dairy cattle were controlled/tested for mastitis, by taking individual samples of milk from each udder quarter to conduct CMT (California mastitis test). In animals whose udder quarters reacted positive to the CMT, further samples were taken for bacteriological analysis, to determine the presence of main causes of mastitis *Staphylococcus (S.) aureus and Streptococcus (Str.) agalactiae,* by implementing standard microbiological methods.

The analysis of variance was used to establish the variability of investigated chemical parameters of milk caused by the impact of various factors. The following model was used to obtain the results of the variance analysis (least square means, determination of the model and significance of individual factors):

$$Y_{ikl} = \mu + G_i + M_k + F_l + eijkl$$

where:

Y_{ikl} = phenotypic value of certain traits included in the analysis,

μ – general mean value,

G_i – fixed effect of the year (i = 1, 2),

M_k – fixed effect of the month of the control (k = 1,..., 12),

F_l – fixed effect of the farm (l = 1, …., 200),

e_{ikl} – other non-determined effects (random error).

The strength of the correlation was determined according to Roemer-Orphal classification (quote by *Latinović, 1996*), whereas the significance was determined at the level of $P<0,001$. All statistical analyses were done by applying appropriate procedures (Proc CORR, Proc GLM) within the statistical software package SAS. 9,1.

Results and Discussion

Results of the investigation of the chemical composition and somatic cell count in collective milk samples taken from family dairy farms, are presented per years of investigation and months of control (aggregate for both years) in Tables from 1 to 4. Table 1 presents statistical significance of the model and results of the variance analysis for individual quality traits of raw milk.

Results of the analysis of variance confirm that the variability of certain chemical parameters of milk was under significant effect of analysed factors. Determination coefficients indicate that the percentage of explained variability of certain milk traits ranged from 0.41 to 0.55, which confirms the significance of investigated variability sources

Table 1. Variance analysis of chemical parameters of milk

	R^2	Df of the model	MS of the model	Df of the residual	MS of the residual	F	P
Milk fat %	0.41	212	4	16815	0.08	54.55	***
Protein %	0.53	212	2	16815	0.02	89.84	***
Lactose %	0.44	212	1	16815	0.01	63.22	***
FFDM %	0.55	212	3	16815	0.03	97.49	***
SC (x 10^3)	0.52	212	3880821	16815	45456.17	85.37	***

SC –Somatic cells; FFDM- Fat free dry matter; Significance: *** P<0.001.

In the analysis of the effects of the study year and month of control, on changes in the chemical composition of milk and somatic cell count in collective milk samples from dairy farms (Table 2), the precise determination of all variability sources which exhibit their influence within this effect, cannot always be made. No doubt, within the effect of the study year, very important are climatic factors and their direct impact on the quality of available food. It should also be mentioned that the effects of the year and month include series of effects which are associated with various zootechnical conditions present on the farm, and which may or may not vary from year to year. These influences can especially be exhibited on private farms, such was the case in this study, where there is often marked variability in regard to housing and nutrition conditions.

The effect of farm on somatic cell count of milk and changes of its chemical composition per months of control, was at the significant level (P<0.001). The effect of the farm is very complex factor which reflects through action of numerous different systematic and non-systematic environment influences, such as nutrition, type and quality of housing facilities, health condition of heads of cattle, climatic conditions, farm management, etc. present variability and intensity of the action of mentioned factors contribute to expression of considerable statistical significance of this factor on studied traits.

Table 2. Results of the variance analysis of certain factors on studied traits of chemical composition of milk and somatic cell count

Factor	df	SC (x 10^3)		Protein (%)		Milk fat (%)		Lactose (%)		FFDM (%)	
		F	p	F	p	F	p	F	p	F	p
Intercept	1	8390	***	10065	***	316182	***	288190	***	41675	***
Year	1	0.023	***	5	0.02	99.2	***	50	***	35	***
Month	11	48.20	***	783	***	467.6	***	459	***	888	***
Farm	200	87.12	***	51	***	29.9	***	41	***	53	***

SC –Somatic cells; FFDM- Fat free dry matter

Based on data presented in Table 3 it can be observed that the highest somatic cell count was recorded in summer months, whereas the somatic cell count for both years was at approximately same level.

Increased somatic cell count during summer months coincides mainly with high daily temperatures which occurred during July and August, and farmers were not able to keep the somatic cell count of milk produced in their dairy herds under control (stress caused by high daily temperatures, inadequate consumption of sufficient quantities of food, etc.).

Table 3. Least square means for basic raw milk quality parameters per years and months of the study

Year	N	SC (x 10^3)	Protein (%)	Milk fat (%)	Lactose (%)	FFDM (%)
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
I	5550	462.43±5.42	3.21±0.003	3.77±0.007	4.55±0.003	8.46±0.004
II	11478	463.02±4.46	3.20±0.003	3.83±0.007	4.53±0.003	8.44±0.004
Month						
I	1369	449.47±7.45	3.24±0.005	3.95±0.009	4.58±0.004	8.52±0.006
II	1425	427.84±7.40	3.22±0.005	3.91±0.010	4.64±0.004	8.50±0.006
III	1715	425.61±7.09	3.18±0.004	3.83±0.010	4.64±0.004	8.50±0.006
IV	1442	410.42±7.44	3.15±0.005	3.77±0.010	4.54±0.004	8.39±0.006
V	1395	430.34±7.44	3.13±0.005	3.65±0.010	4.53±0.004	8.36±0.006
VI	990	460.51±8.46	3.05±0.005	3.57±0.011	4.42±0.004	8.22±0.007
VII	1589	529.18±7.12	3.05±0.004	3.56±0.009	4.45±0.003	8.22±0.006
VIII	1242	536.65±7.75	3.13±0.005	3.62±0.010	4.50±0.004	8.33±0.006
IX	1301	483.92±7.55	3.26±0.004	3.80±0.010	4.53±0.004	8.51±0.006
X	1575	472.94±7.25	3.33±0.004	3.93±0.009	4.54±0.004	8.58±0.006
XI	1430	467.50±7.42	3.33±0.004	3.98±0.009	4.55±0.004	8.59±0.006
XII	1555	444.29±7.17	3.34±0.004	4.04±0.009	4.59±0.004	8.64±0.006

SC –Somatic cells; FFDM- Fat free dry matter

In studies of other authors (*Wells and Ott, 1998),* it is stated that in general the content of these cells in milk is the lowest during winter, and highest during summer, which is associated with increase of incidence of clinical mastitis in cows during summer months, caused by various microorganisms.

Table 4 presents the results of the bacteriological analysis of milk samples on presence of main causes of mastitis.

Data presented in Table 4 shows that the average number of cows which showed positive response to CMT and were bacteriologically tested in both years was 1906 heads of cattle. Of total number of tested cows, in average for two years, in 776 animals *S. aureus* was isolated as cause of mastitis, i.e. in 6.06% in relation to the total number of tested cows. *Str. agalactiae* was isolated in 1130 heads of cattle, which is 8.82% of total number of tested cows during the period of two years. Prior to introduction and wide application of udder disinfection after milking and treatment of cows during dry period, *Str. agalactiae* was the most often isolated cause of mastitis, and now it is eradicated in numerous herds.

Table 4. Results of the tested milk samples in bacteriological analysis

Year	N	No. of controlled animals		Cows with *S.aureus*		Cows with *Str.agalactiae*	
		n	%	n	%(*)	n	%(*)
I	5550	3156	56,86	164	5.20	206	6,53
II	11478	9655	84,12	612	6.34	924	9,57
∑	17028	12811	75.23	776	6.06	1130	8.82
Month							
I	1369	826	60,34	35	4,24	32	3,87
II	1425	904	63,44	53	5,86	138	15,27
III	1715	1259	73,41	86	6,83	97	7,70
IV	1442	1202	83,36	77	6,41	141	11,73
V	1395	1104	79,14	42	3,80	83	7,52
VI	990	854	86,26	19	2,22	107	12,53
VII	1589	1072	67,46	88	8,21	79	7,37
VIII	1242	892	71,82	59	6,61	66	7,40
IX	1301	1126	86,55	60	5,33	105	9,33
X	1575	1068	67,81	74	6,93	84	7,87
XI	1430	1311	91,68	78	5,95	129	9,84
XII	1555	1193	76,72	105	8,80	69	5,78

* percentage in relation to number of tested cows

Intensity of the correlation between analysed parameters in milk and determined statistical significance are presented in Table 5. In this study, statistically highly significant correlation (P<0,001) between all observed parameters in milk was established. Positive, weak, statistically highly significant correlation between the content of milk fat and protein in relation to somatic cell count was established in the study, as well as negative and significant correlation between somatic cell count and content of lactose and fat free dry matter in milk. Also, statistically significant, strong and positive correlation between content of fat free dry matter and lactose, and statistically significant, very strong, positive correlation between content of fat free dry matter in milk and protein content, were established.

Table 5. Results of the study of the correlation strength betwn certain milk quality parameters and somatic cell count, n=17028

Variables	Milk fat %	Protein %	Lactose %	FFDM %	SC (x 10^3)
Milk fat %	1.00	0.38***	0.08***	0.34***	0.06***
Protein %	0.38***	1.00	0.24***	0.88***	0.06***
Lactose %	0.08***	0.24***	1.00	0.61***	-0.27***
FFDM %	0.34***	0.88***	0.61***	1.00	-0.10***
SC (x 10^3)	0.06***	0.06***	-0.27***	-0.10***	1.00

Significance: ***P<0,001

Obtained results can to some extent be compared to results obtained in the research by *Hristov et al. (2006),* who established in the study of correlation between the somatic cell count and content of milk fat and protein, statistically significant and strong negative correlation between SCC and protein content (-0,60) in collective milk samples taken from cows under control.

Based on above mentioned, it can be concluded that daily control of the raw milk entering the dairy plant, as well as individual controls of the collective sample of milk from each dairy farmer, i.e. his dairy herd, represent great help to farmers and veterinary institutions which are engaged in protection of animal health, to react timely on any incidence of subclinical and clinical mastitis, with aim to adequately and appropriately treat dairy cattle with determined higher somatic cell count in their milk. In this way, farmers can have a clear picture of udder health of their dairy animals, and also higher level of hygiene of delivered raw milk to dairy plant is achieved.

Conclusion

Based on results obtained in the study of somatic cell count in collective milk sample and its effect on content of milk fat, protein, lactose and fat free dry matter, the following can be concluded:

The lowest somatic cell count in period of two years under control was registered in winter and autumn months, whereas the average for entire year was ($462x10^3$).

In this study, statistically highly significant correlation ($P<0,001$) between all observed parameters in milk was established. Positive, weak, statistically highly significant correlation between the content of milk fat and protein in relation to somatic cell count (0,06) was established in the study, as well as negative and significant correlation between somatic cell count and content of lactose (-0,27) and fat free dry matter in milk(-0,10).

Of total number of tested cows, in average for two years, in 776 animals *S. aureus* was isolated as cause of mastitis, i.e. in 6.06% in relation to the total number of tested cows. *Str. agalactiae* was isolated in 1130 heads of cattle, which is 8.82% of total number of tested cows during the period of two years.

Results of the variance analysis show that the variability of certain chemical parameters in milk as well as somatic cell count were under significant effect of individual analysed factors (month of control, study year and family farms), as well as under the effect of their interaction.

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Varijabilnost i povezanost osnovnih parametara kvaliteta sirovog kravljeg mleka

N. Memiši, V. Bogdanović, Z. Tomić, A. Kasalica, M. Žujović, N. Stanišić, N. Delić

Rezime

U radu prikazani su godišnji rezultati ispitivanja broja somatskih ćelija u mleku, mlečne masti, proteina, laktoze i suve materije bez masti, u zbirnim uzorcima mleka krava u intenzivnoj proizvodnji u toku dve proizvodne godine. Ispitivanja su izvršena kontrolom zbirnih uzoraka mleka od približno 3000 krava sa porodičnih farmi. Prosečni broj somatskih ćelija je bio $462x10^3$ u 1 ml zbirnog mleka (uz variranje od 410,43 do 536,06 x 10^3 u 1 ml), prosečni sadržaj proteina je bio 3,21%, mlečne masti 3,76%, laktoze 4,54% i suve materije bez masti 8,46%. Utvrđene su statistički značajne razlike u broju somatskih ćelija utvrđenih na zbirnom uzorku mleka u odnosu na mesec kontrole.

U ovom radu je utvrđena pozitivna i statistički signifikantna korelacija ($P<0,001$) između sadržaja mlečne masti i proteina u mleku i broja somatskih ćelija, i negativna i statistički signifikantna ($P<0,001$) korelacija između broja somatskih ćelija i sadržaja laktoze i suve materije bez masti u zbirnom uzorku mleka. Utvrđivanje odn. merenj broja somatskih ćelija u zbrinom mleku je ključni faktor u oceni kvaliteta mleka zapata, i koristi se i u određivanju cene otkupljenog mleka, i ukazuje na zdravlje vimena mlečnih grla u zapatu i omogućava farmi da prati uspeh programa za kotnrolu mastitisa u zapatu.

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