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Effect of somatic cell counts in milk on its quality depending on cow breed and season

Wpływ liczby komórek somatycznych w mleku na jego jakość w zależności od rasy krów i pory roku

Summary. The aim of the present work was to determine the physicochemical quality of milk in relation to the bovine udder health status, taking cows' breed and production season into consideration. The studies were conducted throughout three successive years (2006–2008) on milk samples collected from the cows of three breeds, i.e. Polish Holstein-Friesian Black and Red-White variety, Simental and Jersey. All cows were managed in free-stall barns and their feeding system, in winter as well in summer season, was based on TMR (total mixed ratio). A total of 1822 milk samples were researched. In each sample the somatic cell count (SCC), chemical composition as well as acidity were examined. The research material within each breed was assigned into four groups according to SCC. It was found that the increase of SCC in milk first of all led to a decrease of casein share in crude protein and lactose content, with a slight decrease in fat content. It should be marked that the statistically significant changes in some milk components content were noted only when SCC exceeded 500 000 cells cm^{-3}, so in the milk which does not meet the current quality requirements.

Keywords: milk quality, somatic cell count, cows' breed

INTRODUCTION

Despite the extensive research effort focused on dairy cattle improvement and educational programs for producers, mastitis has remained as one of top factors affecting milk production and its nutritional value. Somatic cell count (SCC) is the most widely accepted indicator of the mammary gland health and milk quality and at the same time, one of the criteria for milk acceptance by a purchase point. In Poland and other European Union countries, a requirement laid down [Regulation (EC) No 853/2004] for incoming raw milk established 400 000 SCC cm^{-3} as the upper limit. However, Canada agreed on threshold of 500 000 SCC cm^{-3} in milk for consumption and the USA has the highest upper limit for SCC – 750 000 cells cm^{-3} [Schukken *et al.* 2003]. According to many authors [Urech *et al.* 1999, Hamann 2002, Smith 2002, Pyorala 2003, Malinowski *et al.* 2008], an udder quarter producing milk of 200 000 SCC cm^{-3} or more is very likely to exhibit clinical manifestations of subclinical mastitis. Elevated count of somatic cells leads to decreased milk efficiency, lower nutritional and technological milk value and consequently, serious economic losses. Huijps *et al.* [2008] reported that the mastitis-induced financial losses amount to average 78 Euros per cow annually. In Poland, ca 30–50% of dairy cow population show mastitis symptoms every year, in that clinical forms of the disease are recognized in 2–5% cows [Głowacki 2006].

The aim of the present research was evaluation of physicochemical quality of milk subject to udder health status, including cow breed and production season.

MATERIAL AND METHODS

The studies were carried out during three successive years (2006–2008) on milk samples collected from cows of three breeds: Polish Holstein-Friesian Black-White and Red-White variety, Simental and Jersey. All the free stall housed cows were fed in the TMR feeding system (maize silage, hay silage, concentrate). The milk samples were taken individually from each cow during the trial milkings twice a year, i.e. in the winter and summer season. A total of 1822 milk samples were included into studies (winter – 946; summer – 876). Each milk sample was examined for SCC using the flow cytometry technology Somacount 150 (Bentley), chemical composition by an Infrared Milk Analyzer (Bentley), a casein percentage [AOAC 1998] and active acidity – pH using a pH-meter and potential (titratable) acidity expressed in °SH [PN-68/A-86122].

Data of daily milk yield was provided by the breeding records run by the Polish Federation of Cattle Breeders and Dairy Farmers.

The research material within each breed was divided into 4 groups according to the SCC values : I – up to 100 000 SCC cm^{-3}; II – 101–400 000 SCC cm^{-3}; III – 401–500 000 SCC cm^{-3}; IV > 500 000 ≤ 1 million SCC cm^{-3}. The data made the basis for statistical analyses of milk parameters.

The obtained study results were analyzed statistically using the StatSoft Inc. ver. 6 (StatSoft Inc. 2003) program based on two-factor variance analysis. Significance of differences was determined by the Fisher's LSD test. To establish a relationship between SCC and milk parameters, Pearson correlation coefficients were computed.

RESULTS AND DISCUSSION

Daily milk efficiency of the cows under investigations averaged in the summer period from 19.86 kg in Simental up to 21.53 kg in Polish Holstein-Friesian Black-White variety. Whereas in the winter season, from 20.05 kg up to 25.58 kg, respectively. Increasing the SCC in cow milk caused a progressive decrease in daily milk yield.

Elevated SCC is, as a rule, associated with changes in milk chemical composition that deriorate milk nutritional value. The present researches have revealed that rising SCC numbers (regardless of cow breed or season) produces changes in a crude protein content, in that casein (Tab. 1 and 2). The observed declined tendency in crude protein concentration persisted in most cases, including group III. While, in group IV, i.e. with SCC exceeding 500 000 SCC cm^{-3}, there was found slight statistically insignificant growth of this constituent. It should be highlighted that the highest crude protein content was determined in milk from Jersey cows breed in the winter period. Lindmark-Månsson *et al*. [2006] reported that total crude protein concentration usually does not undergo any changes at the SCC count below 1 million cm^{-3}.

According to expectations, a substantive decrease in a casein content with the concurrent SCC counts elevation was observed in both seasons, the highest between group III and IV. In the summer period, this constituent level declined in the last group as compared to group I – average by 6.5% ($p \leq 0.05$), while in milk obtained from the Polish Holstein-Friesian Black-White variety cows by as high as 7.4% ($p \leq 0.05$). In the winter season, the differences ranged from 3.6% in milk from Simental up to 4.9 and 5.5% in Polish Holstein-Friesian Red- and Black-White variety cows' milk and the final average was 4.2%. A markedly negative relationship between SCC and a milk casein content was confirmed by relatively high correlation coefficients (Tab. 4).

A fat level also showed a downwards tendency with the SCC increase, but significant differences were determined only in milk from Jersey breed cows at the summer period (0.25%) and in milk obtained from Simental in the winter season (0.24%). Ogola *et al*. [2007] and Forsbäck *et al*. [2009] conclude that the changes in protein and fat content in milk with elevated somatic cell numbers arise from the increased risk for proteolysis and lipolysis occurrence.

Rising the SCC in milk caused a decreased lactose level. A difference between group I and IV reached 0.20% ($p \leq 0.01$) in both periods. In the winter season, milk from Holstein-Friesian Black-White variety and Simental cows displayed a significant decline in lactose concentration in a group with SCC surpassing 400 000 SCC cm^{-3}. A significant negative relationship between the SCC and a milk lactose content was indicated by the correlation coefficients (Tab. 4). The changes recorded in each milk constituent with the concurrent SCC elevation induced some changes in a dry matter percentage as well. Regardless of a production season, milk with the lowest SCC level (group I) as compared to milk from IV group cows, contained more dry matter by 0.45% in summer and by 0.52% in winter.

Higher SCC, according to Hamann [2002], evidences disturbed milk secretion, which causes lower daily milk yield, changes in its chemical composition and deteriorated technological properties. It is consistent with the research findings reported by other authors [Bernatowicz *et al.* 2004, Giersz *et al.* 2004, Piccinini *et al.* 2006, Berlung 2007, Barłowska *et al*. 2009, Modesto *et al.* 2009]. It was found that increased SCC declined significantly the milk efficiency and a casein level accompanied by slight changes in crude protein concentration.

A key criterion for milk acceptance by purchase points proves to be milk acidity, both potential (°SH) and active (pH), which serves to evaluate milk freshness. Titratable acidity of raw milk should range between 6.0°SH and 7.5°SH, while pH – from 6.6 up to 6.8. The obtained research results (Tab. 1 and 2) are contained within the required intervals and that gives evidence of freshness of the analyzed milk. Increased SCC has been proven to cause a significant decline in milk potential acidity in the winter period (from 7.28°SH to 6.57°SH). In the studies by Ogola *et al*. [2007], no significant impact of the SCC on pH value was recorded, but interestingly, the SCC growth was accompanied by the elevation in milk active acidity.

Table 1. Chemical content and acidity of milk obtained from three cows' breeds in summer season in relation to SCC ($\bar{x}$ ±SD)

Tabela 1. Skład chemiczny i kwasowość mleka trzech ras krów w sezonie letnim w zależności od LKS ($\bar{x}$ ±SD)

Breed Rasa	SCC group Grupa LKS	n[1]	Crude protein Białko ogólne (%)	Casein in crude protein share Udział kazeiny w białku (%)	Fat Tłuszcz (%)	Lactose Laktoza (%)	Dry matter Sucha masa (%)	°SH	pH
Polish Holstein-Friesian	I	92	3.61 ± 0.45^{ab}	79.1 ± 0.09^{b}	4.45±0.09	4.77 ± 0.23^{b}	13.55±0.34	7.33±0.88	6.68±0.08
Black-White variety	II	53	3.69 ± 0.49^{b}	76.5 ± 0.11^{ab}	4.33±0.13	4.78 ± 0.20^{b}	13.40±0.29	6.59±0.92	6.66±0.09
Polska holsztyńsko-fryzyjska	III	74	3.50 ± 0.48^{a}	75.4 ± 0.07^{ab}	4.36±0.14	4.70 ± 0.22^{ab}	13.25±0.31	6.92±0.97	6.68±0.07
odmiany czarno-białej	IV	44	3.58 ± 0.36^{ab}	71.7 ± 0.08^{a}	4.25±0.11	4.62 ± 0.30^{a}	13.12±0.18	6.72±0.75	6.68±0.08
Polish Holstein-Friesian	I	47	3.59 ± 0.39^{B}	79.4±0.07	4.37±0.59	4.91 ± 0.18^{b}	13.49±0.22	7.51±0.76	6.67±0.06
Red-White variety	II	68	3.49 ± 0.31^{AB}	77.3±0.06	4.26±0.70	4.82 ± 0.21^{b}	13.31±0.19	6.60±0.83	6.71±0.11
Polska holsztyńsko-fryzyjska	III	79	3.34 ± 0.46^{A}	77.1±0.08	4.28±0.78	4.78 ± 0.18^{b}	13.14±0.36	6.82±0.77	6.68±0.08
odmiany czerwono-białej	IV	45	3.39 ± 0.33^{AB}	72.7±0.07	4.26±0.62	4.60 ± 0.23^{a}	12.95±0.29	6.81±0.83	6.67±0.09
	I	54	3.78±0.35	77.9±0.08	4.24±0.36	4.79 ± 0.23^{b}	13.43±0.30	7.44±0.87	6.72±0.07
Simental	II	48	3.75±0.54	76.7±0.06	4.17±0.66	4.71 ± 0.18^{ab}	13.40±0.34	7.58±1.02	6.69±0.12
Simentalska	III	55	3.72±0.33	74.6±0.10	4.20±0.68	4.76 ± 0.16^{b}	13.32±0.25	7.64±0.77	6.72±0.10
	IV	43	3.70±0.42	72.0±0.10	4.18±0.51	4.59 ± 0.29^{a}	13.21±0.19	6.83±0.76	6.73±0.07
	I	36	4.02±0.47	78.9±0.13	5.10 ± 0.68^{b}	4.83±0.24	14.66±0.23	7.35±0.68	6.71±0.05
Jersey	II	57	3.86±0.50	77.6±0.13	5.07 ± 0.31^{b}	4.82±0.25	14.49±0.31	7.10±0.86	6.70±0.04
	III	45	3.72±0.55	76.4±0.17	4.92 ± 0.77^{ab}	4.71±0.12	14.10±0.22	7.25±0.56	6.75±0.06
	IV	36	3.82±0.50	73.3±0.16	4.85 ± 0.99^{a}	4.69±0.31	14.04±0.19	6.80±0.47	6.76±0.07
	I	229	3.76±0.60	79.0 ± 0.12^{b}	4.49±0.66	4.83 ± 0.24^{B}	13.78±0.35	7.42±0.82	6.69±0.07
Total – Razem	II	226	3.71±0.59	77.1 ± 0.15^{ab}	4.43±0.45	4.78 ± 0.21^{AB}	13.63±0.29	7.00±0.87	6.68±0.09
	III	253	3.58±0.54	76.1 ± 0.17^{ab}	4.45±0.57	4.74 ± 0.28^{AB}	13.48±0.31	7.19±0.75	6.71±0.08
	IV	168	3.63±0.49	72.5 ± 0.15^{a}	4.38±0.66	4.63 ± 0.30^{A}	13.33±0.28	6.79±0.77	6.70±0.08

[1]n – number of cows in group

[1]n – liczba krów w grupie

a, b – significant at $p \leq 0.05$; A, B – significant at $p \leq 0.01$

a, b – istotne przy $p \leq 0.05$; A, B – istotne przy $p \leq 0.01$

Table 2. Chemical content and acidity of milk obtained from three cows' breeds in winter season in relation to SCC ($\bar{x}$ ±SD)

Tabela 2. Skład chemiczny i kwasowość mleka trzech ras krów w sezonie zimowym w zależności od LKS ($\bar{x}$ ±SD)

Breed Rasa	SCC group Grupa LKS	n[1]	Crude protein Białko ogólne (%)	Casein in crude protein share Udział kazeiny w białku (%)	Fat Tłuszcz (%)	Lactose Laktoza (%)	Dry matter Sucha masa (%)	ºSH	pH
Polish Holstein-Friesian Black-White variety Polska holsztyńsko--fryzyjska odmiany czarno-białej	I	106	3.95±0.54^{b}	75.8± 0.08^{b}	4.62±0.78	5.01±0.20^{b}	14.28±0.44	7.10±0.80^{b}	6.71±0.10^{a}
	II	96	3.86±0.45^{ab}	74.7± .09^{ab}	4.60±0.79	4.91±0.21^{ab}	6.85±0.79^{ab}	6.74±0.11^{ab}	6.74±0.11^{ab}
	III	48	3.70±0.54^{a}	74.6± .07^{ab}	4.58±0.73	4.89±0.19^{a}	6.63±0.75^{a}	6.77±0.16^{ab}	6.77±0.16^{ab}
	IV	46	3.74±0.48 ^{a}	70.3± 0.07^{a}	4.50±0.69	4.86±0.23^{a}	6.60±0.94^{a}	6.81±0.12^{b}	6.81±0.12^{b}
Polish Holstein-Friesian Red-White variety Polska holsztyńsko--fryzyjska odmiany czerwono-białej	I	88	3.90±0.45	76.1±0.02^{b}	4.81±0.66	5.02±0.17^{b}	7.40±0.70^{B}	6.67±0.06^{a}	6.67±0.06^{a}
	II	56	3.82±0.32	76.0±0.03^{b}	4.79±0.66	5.01±0.19^{b}	7.32±0.76^{AB}	6.69±0.07^{a}	6.69±0.07^{a}
	III	66	3.75±0.40	74.8±0.03^{ab}	4.69±0.52	4.99±0.23^{ab}	7.30±0.86^{AB}	6.74±0.08^{ab}	6.74±0.08^{ab}
	IV	33	3.74±0.56	71.2±0.02^{a}	4.61±0.42	4.88±0.13^{a}	6.33±0.43^{A}	6.80±0.05^{b}	6.80±0.05^{b}
Simental Simentalska	I	86	3.86±0.31	75.7±0.06	4.39±0.61^{b}	4.94±0.20^{B}	7.19±0.91	6.76±0.09	6.76±0.09
	III	54	3.79±0.28	73.9±0.02	4.37±0.69^{ab}	4.82±0.19^{AB}	6.92±0.72	6.78±0.06	6.78±0.06
	II	46	3.70±0.36	74.0±0.05	4.29±0.63^{ab}	4.75±0.22^{A}	6.85±0.59	6.76±0.09	6.76±0.09
	IV	41	3.69±0.18	72.1±0.03	4.15±0.68^{a}	4.72±0.24^{A}	6.42±0.73	6.80±0.08	6.80±0.08
Jersey	I	62	4.14±0.36^{a}	76.9±0.08	5.47±0.80	4.91±0.18^{B}	7.43±0.93	6.63±0.07	6.63±0.07
	III	54	4.36±0.35^{b}	73.7±0.07	5.45±1.05	4.84±0.17^{AB}	7.35±0.77	6.67±0.06	6.67±0.06
	II	36	4.30±0.27^{ab}	73.5±0.05	5.40±1.13	4.81±0.16^{AB}	6.90±0.94	6.65±0.06	6.65±0.06
	IV	28	4.33±0.37^{ab}	72.6±0.09	5.35±0.33	4.63±0.28^{A}	6.63±0.76	6.69±0.12	6.69±0.12
Total – Razem	I	342	3.98±0.49	76.1±0.08	4.82±0.81	4.97±0.20	7.28±1.06^{b}	6.74±0.13	6.74±0.13
	III	260	3.95±0.51	74.9±0.09	4.80±0.79	4.90±0.22	7.16±1.12^{ab}	6.78±0.10	6.78±0.10
	II	196	3.88±0.41	74.5±0.07	4.71±0.68	4.86±0.19	6.90±1.01^{ab}	6.74±0.09	6.74±0.09
	IV	148	3.87±0.44	71.9±0.07	4.64±0.65	4.77±0.23	6.57±0.89^{a}	6.78±0.11	6.78±0.11

[1]n – number of cows in gr oup, [1]n – liczba krów w grupie, a, b – significant at $p \leq 0.05$; A, B – significant at $p \leq 0.01$, a, b – istotne przy $p \leq 0.05$; A, B – istotne przy $p \leq 0.01$

Table 3. Results of multifactorial variance analysis for analyzed milk components
Tabela 3. Wyniki wieloczynnikowej analizy wariancji dla analizowanych składników mleka

Factor Czynnik	Crude protein Białko ogólne (%)	Casein in crude protein share Udział kazeiny w białku (%)	Fat Tłuszcz (%)	Protein to fat proportion Stosunek białka do tłuszczu	Lactose Laktoza (%)	Dry matter Sucha masa (%)	°SH	pH
Breed Rasa	xx	xx	xx	xx	xx	xx	xx	xx
SCC LKS	x	xx	ns	ns	xx	xx	x	x
Season Sezon	xx	ns	xx	ns	xx	xx	ns	ns
Breed × SCC Interactions Interakcje rasa × LKS	ns	ns	ns	ns	x	ns	ns	ns
Breed × season interactions Interakcje rasa × sezon	xx	xx	xx	ns	x	xx	ns	xx
SCC × season interactions Interakcje LKS × sezon	x	x	ns	ns	ns	ns	ns	ns
Breed × SCC × season interactions Interakcje rasa × LKS × sezon	x	ns	xx	ns	ns	xx	ns	ns

Factor influence: x – at $p \leq 0.05$; xx – at $p \leq 0.01$; ns – not stated
Wpływ czynnika: x – przy $p \leq 0.05$; xx – przy $p \leq 0.01$; ns – nie stwierdzono

Table 4. Correlation coefficients (r) between SCC and chosen milk components
Tabela 4. Współczynniki korelacji (r) pomiędzy LKS a wybranymi składnikami mleka

Breed Rasa	Crude protein Białko ogólne	Casein in crude protein share Udział kazeiny w białku	Fat Tłuszcz	Lactose Laktoza	Dry matter Sucha masa	pH	°SH
Polish Holstein-Friesian Black-White variety Polska holsztyńsko-fryzyjska odmiany czarno-białej	-0.049	-0.529^{xxx}	-0.142	-0.198^{x}	-0.030	0.195^{x}	-0.203^{x}
Polish Holstein-Friesian Red-White variety Polska holsztyńsko-fryzyjska odmiany czerwono-białej	-0.057	-0.527^{xxx}	-0.136	-0.171^{x}	-0.066	0.270^{x}	-0.312^{xx}
Simental Simentalska	-0.021	-0.408^{xx}	-0.254^{x}	-0.276^{x}	-0.016	0.096	-0.165^{x}
Jersey	-0.049	-0.418^{xx}	-0.276^{x}	-0.444^{xx}	-0.058	0.061	-0.182^{x}
Total Razem	-0.045	-0.460^{xx}	-0.198^{x}	-0.257^{x}	-0.021	0.149	-0.205^{x}

^{x} – $P \leq 0.05$; ^{xx} – $P \leq 0.01$; ^{xxx} – $P \leq 0.001$

The final results of variance analysis (Tab. 3) have indicated that a breed had significant effect on all milk parameters under study and, as the only factor, it did affect a ratio between protein and fat. As for the somatic cell count, there was shown the impact of this factor on a crude protein content ($p \leq 0.05$), lactose ($p \leq 0.01$) and dry matter ($p \leq 0.01$), a casein percentage ($p \leq 0.01$) and milk acidity ($p \leq 0.05$). Season was also noted to influence significantly ($p \leq 0.01$) each milk constituent and parameter, except for casein and acidity. Significant interactions between cow breed and production season were not recorded only for protein to fat ratio and titrable acidity. The significant interrelations between cow breed and SCC were reported solely for a lactose content ($p \leq 0.05$), while between season and SCC count – for crude protein and casein level ($p \leq 0.05$). Some significant interdependences between three analyzed factors were found for crude protein, fat and dry matter concentration.

CONCLUSIONS

1. A rise in somatic cell numbers (regardless of cow breed and season) translates into a direct decline of a casein content in crude protein and lactose level, with a significant decrease in fat concentration.

2. The significant changes in milk constituents were recorded only when the SCC exceeded 500 000 cm^{-3}, that is in milk that does not meet the current regulatory quality standards.

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Streszczenie. Celem badań była ocena jakości fizykochemicznej mleka w zależności od stanu zdrowotnego wymienia, z uwzględnieniem rasy krów oraz pory roku. Badania przeprowadzono w okresie trzech kolejnych lat (2006–2008) na próbach mleka pobranych od krów 3 ras, tzn.: od polskiej holsztyńsko-fryzyjskiej odmiany czarno-białej i czerwono-białej, simentalskiej oraz jersey. Wszystkie krowy utrzymywano w oborach wolnostanowiskowych, a ich żywienie, zarówno w sezonie zimowym, jak i letnim, prowadzono systemem TMR. Łącznie badaniami objęto 1822 próby mleka. W każdej próbie oznaczono: liczbę komórek somatycznych (LKS), skład chemiczny oraz kwasowość. Materiał badawczy w obrębie każdej rasy podzielono na 4 grupy według LKS. Wzrost LKS w mleku prowadził zwłaszcza do obniżenia udziału kazeiny w białku ogólnym i zawartości laktozy, przy nieznacznym spadku zawartości tłuszczu. Należy zaznaczyć, że do istotnych zmian w zawartości niektórych składników mleka dochodziło z reguły dopiero wówczas, gdy LKS przekraczała 500 tys. cm^{-3}, a więc w mleku niespełniającym obecnie obowiązujących wymagań jakościowych.

Słowa kluczowe: jakość mleka, liczba komórek somatycznych, rasa krów