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FACTORS ASSOCIATED WITH THE LEVELS OF SOMATIC CELLS AND MICROORGANISMS IN BULK TANK MILK

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The aim of this study was to analyse the association between factors characterising dairy herd management and the levels of somatic cell count (SCC), and total microorganisms count (TMC) in bulk tank milk. The investigations were carried out in 2005 in 187 family farms (herd size from 6 to 60 cows), situated in adjacent parts of Warmia & Mazury, and Mazowsze regions. Based on annual geometric means, all the farms were divided into those with low and elevated SCC level (<200,000 *vs*. 200,000–400,000 cells/mL), and with low and elevated TMC level in milk (<50,000 *vs*. 50,000–100,000 cfu/mL). The milk was characterised by low SCC level in 55 farms (29.4%), whereas TMC level was low in 65 farms (34.8%).

The following factors were associated with the low level of SCC: small herd size, tie-stall system of cow housing, grazing cows, use of advisory service, use of antibiotics at cow dry-off, dry storing of milking clusters between milkings, post-milking teat dipping, regular use of California Mastitis Test, treatment of clinical cases of *mastitis* with antibiotics in selected cows only, use of whole straw in cow feeding, and use of salt-licks containing microminerals.

Factors associated with the low level of TMC were: large herd size, colostrum feeding to the newborn calf by bucket, individual housing of replacement heifers older than 3 months, pipe-line system of milking, dry storing of milking clusters between milkings, pre-milking udder and teat cleaning with wet towel soaked with a disinfectant, tank system of milk cooling and storage after milking, and regular calculation of feeding rations for cows.

INTRODUCTION

Somatic cell count (SCC) and total microorganisms count (TMC) are the most important criteria characterising hygienic quality of raw milk. The SCC is strictly correlated with health status of the udder. The generally accepted view is that the udder in a cow with SCC over 200,000 cells/mL of milk is infected (*mastitis*). Contrary to SCC, the TMC is affected both by microbiological status of the udder, as well as hygiene of milking and milk handling after milking. Increased SCC level is related to losses in milk production and impaired milk quality. Milk high in SCC provides less casein for cheese production and the protein generally is of lower quality. Raw milk with elevated SCC and/or TMC is also known to reduce shelf-life of dairy products. Moreover, high concentration of pathogenic microbes in milk increases the risk of zoonoses. Apart from milk quality and safety as raw material for processing, animal welfare is becoming an increasingly important issue.

After the accession of Poland to EU, the regulations in force in the EU countries have been imposed, according to which only milk containing less than 400,000 somatic cells and 100,000 colony forming units (cfu) in 1 mL can be classified as suitable for processing. As the adaptation process of dairy sector to the EU regulations had been evolutional and lasted at least 5 years preceding the accession, a number of studies were undertaken, the aim of which was to analyse the association between selected environmental factors and SCC and TMC in the production circumstances [*e.g*. Skrzypek, 2002, 2003, 2006; Skrzypek & Kujawa-Kroll, 2002; Kamieniecki *et al.*, 2004]. However, these studies were conducted in Wielkopolska and Pomorze Zachodnie regions only.

The aim of this study was to analyse the association between a wide spectrum of factors characterising dairy herd management and the level of SCC and TMC in bulk tank milk. The analysis was carried out in north-eastern part of Poland on a large group of family dairy farms. All possible factors known earlier to be associated with the hygienic quality of raw milk were taken into account in order to identify those that had the highest probability of impact on the analysed parameters in the environment studied.

MATERIAL AND METHODS

The study was carried out in 187 family farms, situated in neighbouring parts of Warmia & Mazury and Mazowsze regions. Between January and March 2006 a direct survey was performed in the analysed farms, using a questionnaire consisting of 68 questions, divided into the following sections: general herd management and animal housing, avail-

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ability of runs and pastures for cows, rearing of calves and replacement heifers, late pregnancy and dry period management, milking equipment, hygiene of udder and teats, milk handling after milking, correction of hoofs, mastitic cow treatment and culling, cow feeding. Thereafter, data on SCC and TMC in bulk tank milk were collected for each farm for the whole year 2005. An accredited laboratory performed analyses of both parameters for each farm twice a month. SCC was determined with a Fossomatic counter (Foss Electric, Hillerød, Denmark) and TMC was determined using a standard plate count method [PN–A–86002: 1999].

For both SCC and TMC, annual geometric means were calculated for each farm. Thereafter, all the farms were divided into those with low and elevated SCC level (<200,000 and 200,000-400,000 cells/mL), and low and elevated TMC level in milk (<50,000 and 50,000-100,000 cfu/mL). In both cases the criterion for division was the midpoint of the range of values, which according to current EU regulations permit classifying milk as suitable for processing.

Statistical calculations were performed using a one-way analysis of variance for herd size comparisons, and a chi-square test for frequency comparisons. The significance of differences between groups of farms was characterised using 3 levels of probability (p): 0.01, 0.05, and 0.10.

RESULTS AND DISCUSSION

In the investigated material, the proportion of small (6–15 cows), average (16–25 cows), and large farms (26–60 cows) was 32.2, 32.8, and 35.0%, respectively. The geometric means for SCC and TMC were 235,000 cells/mL (from 29,000 to 389,000) and 53,000 cfu/mL of milk (from 9,000 to 97,000), respectively. Thus, all the farms fulfilled current EU recommendations for the milk that can be classified as suitable for processing. Correlation coefficient between SCC and TMC was 0.29 ($p \leq 0.01$), which corresponds with results of the study by Skrzypek [2006].

The numbers of farms in which milk was characterised by low levels of SCC and TMC were 55 (29.4%) and 65 (34.8%), respectively.

An average number of cows was lower in the low SCC herds than in the elevated SCC herds (14.0 *vs*. 23.1 cows; $p \leq 0.01$), whereas an average number of cows in the low TMC herds was higher than in the elevated TMC herds (22.1 *vs.* 19.6 cows; $p \leq 0.01$). Similar relationship between herd size and SCC as well as TMC was found in other studies performed in Poland [Skrzypek & Kujawa-Kroll, 2002; Skrzypek, 2003, 2006].

In Table 1 there are presented factors significantly associated with the level of SCC. A tie-stall system of cow housing was correlated with low SCC, while SCC was elevated in farms practicing a free-stall system ($p \leq 0.10$). Similar relationship was found in studies of Skrzypek [2002] and Köster *et al.* [2006]. These authors suggest that it was an effect of generally low cow hygiene in free-stall barns, resulting from less comfortable conditions provided by this system. However, because in the present study the free-stall system was used in the largest herds only, it has to also be taken into account that the relationship found could have been an effect of herd size that was mentioned above.

Nearly in all low SCC farms cow grazing was practised (98.2% *vs*. 77.3% for elevated SCC herds). This relationship is in agreement with observations of Kamieniecki *et al*. [2004] and Skrzypek [2006]. It can be presumed that this effect was

TABLE 1. Factors significantly associated with the level of somatic cell count (SCC) in milk.

Factors and their description		Distribution of herds into 2 groups according to annual geometric mean for SCC				Probability of differences between groups of herds
		Low level (<200,000 cells/mL)		Elevated level (200,000 to 400,000 cells/mL)		
		N	%	N	%	
Type of stalls for cows	Tie	55	100.0	125	94.7	p 0.10
	Free	0	0.0	7	5.3	
Grazing cows	No	1	1.8	30	22.7	p 0.01
	Yes	54	98.2	102	77.3	
Regular use of advisory service	No	17	30.9	76	57.6	p 0.01
	Yes	38	69.1	56	42.4	
Use of antibiotics at cow dry-off	No	27	49.1	108	81.8	p 0.01
	Yes	28	50.9	24	18.2	
Storing of milking clusters between milkings	Dry	51	92.7	98	74.2	p 0.01
	Dipping	4	7.3	34	25.8	
Post-milking teat dipping	No	26	47.3	81	61.4	p 0.10
	Yes	29	52.7	51	38.6	
Regular use of California Mastitis Test	No	2	3.6	28	21.2	p 0.01
	Yes	53	96.4	104	78.8	
Treatment of clinical cases of *mastitis* with antibiotics	All cows	6	10.9	42	31.8	p 0.01
	Selected cows	49	89.1	90	68.2	
Use of whole straw in cow feeding	No	0	0.0	29	22.0	p 0.01
	Yes	55	100.0	103	78.0	
Use of "coloured" salt-licks (containing micro-minerals)	No	21	38.2	78	59.1	p 0.01
	Yes	34	61.8	54	40.9	

due to a positive influence of the grazing system on animal hygiene and welfare compared to other options of cow management during the so-called summer season.

Regular use of advisory service was advantageously associated with SCC level. Such a relationship has not been reported in the literature, however, Hutton *et al*. [1990] found that farmers who pursue to be familiar with current knowledge on dairy herd management are more effective producers of low SCC milk.

Use of antibiotics at cow dry-off was much more frequent in low SCC farms than in farms with elevated SCC level (50.9 *vs*. 18.2%, respectively) and the relationship appeared to be very important, as assessed by the size of chi-square estimate ($\chi^2 = 20.71$; $p \leq 0.01$). Barkema *et al.* [1998], Robert *et al.* [2006], and Skrzypek [2006] report a similar correlation of this routine with SCC. The onset of dry period is under particular risk for new intramammary infections because of the stress caused by usually imposed cessation of milk production, which is enlarged by a decreased cow resistance to infectious disease, naturally occurring throughout the dry period and caused by the metabolic stress [Goff & Kimura, 2002]. Therefore, Robert *et al.* [2006] based on analysis of all published results of research studies (meta-analysis) recommend use of antibiotics at dry-off in all cows. Although common use of antibiotics in farm animals increases the risk for development of antibiotic resistance in pathogenic bacteria for man [Malinowski *et al*., 1997], a recently published review [Truszczyński & Pejsak, 2006] clearly shows that the risk of transfer of antibiotic resistance from the animals to the consumer is much smaller than it has been claimed.

Storing milking clusters between milkings dry followed by their washing and disinfection was associated with lower SCC level compared to dipping in clean water or water containing a disinfectant ($p \leq 0.01$). Skrzypek [2006] observed a corresponding relationship, as dry storing decreased the microbiological contamination of milk compared with dipping.

Practicing post-milking teat dipping (and disinfection) was more frequent in the low SCC herds compared to the elevated SCC herds (52.7 *vs*. 38.6%; $p \leq 0.10$). The role of this procedure in preventing from *mastitis* is very well documented [Malinowski, 2000; Nickerson *et al*., 2004] and it appears to be particularly effective in protecting the udder against the infectious pathogens (*e.g. Staph. aureus* and *Strep. agalactiae*).

California Mastitis Test (CMT) was regularly used in almost all low SCC herds, whereas in elevated SCC herds it was used less frequently (96.4 *vs*. 78,8%; $p \leq 0.01$). The very best point of this procedure is that it enables immediate detection of inflammatory process in particular quarters of the udder and application of appropriate treatment. Efficacy of CMT in decreasing SCC in bulk tank milk was recently proved in the studies of Chassagne *et al*. [2005], van Schaik *et al*. [2005], and Skrzypek [2006].

Treatment of clinical cases of *mastitis* with antibiotics in selected cows only appeared to be more effective than treatment of all cows afflicted with the disease ($p \leq 0.01$), which is in agreement with recent results of Skrzypek [2006]. Malinowski *et al.* [1997] and Barkema *et al.* [1998] recommend an individual approach in using antibiotics for *mastitis* treatment, preceded by a test for susceptibility of pathogens residing in the udder to antibiotics. This strategy enables an optimum cure of the cow and protects against development of increased antibiotic resistance in the treated animals.

Use of whole (uncut) straw in cow feeding was advantageously and strongly ($\chi^2 = 14.30$; $p \leq 0.01$) related to SCC level. This result is rather surprising as straw decreases energy concentration in the ration, which may have negative consequences for udder resistance to infections [Suriyasathaporn *et al.*, 2000; Goff & Kimura, 2002; Kamieniecki *et al*., 2004; Skrzypek, 2006]. It is likely that the reason for the relationship found was that not all straw which is administered to cows is eaten and the excess serves as an additional source of litter. Namely, abundant use of straw for stall littering increases substantially the comfort of the cow [Tuyttens, 2005], which may be associated with good udder health and hence with low concentration of somatic cells in the milk.

TABLE 2. Factors significantly associated with the level of total microorganisms count (TMC) in milk

Factors and their description		Distribution of herds into 2 groups according to annual geometric mean for TMC				Probability of differences between groups of herds
		Low level (<50,000 cfu/mL)		Elevated level (50,000 to 100,000 cfu/mL)		
		N	%	N	%	
System of colostrum feeding to the newborn calf	Sucking	6	9.2	25	20.5	p 0.05
	Bucket	59	90.8	97	79.5	
Housing system of replacement heifers older than 3 months	Individual	33	50.8	43	35.2	p 0.05
	Group	32	49.2	79	64.7	
System of milking	Bucket	43	66.2	97	79.5	p 0.05
	Pipe-line	22	33.8	25	20.5	
Storage of milking cluster between milkings	Dry	57	87.7	92	75.4	p 0.05
	Dipping	8	12.3	30	24.6	
Pre-milking udder and teat cleaning with wet towel soaked with a disinfectant	Yes	12	18.5	10	8.2	p 0.05
	Washing	53	81.5	112	91.8	
System of milk cooling and storage after milking	Bucket	0	0.0	8	6.6	p 0.05
	Tank	65	100.0	114	93.4	
Regular calculation of feeding rations for cows	No	7	10.8	28	23.0	p 0.05
	Yes	58	89.2	94	77.0	

"Coloured" salt-licks were used more frequently in the low SCC herds compared to the elevated SCC herds (61.8 *vs*. 40.9%, respectively; $p \leq 0.01$). Such salt-licks contain trace minerals (among others selenium and copper) that have a direct stimulatory effect on the functioning of the immune system and for that reason can increase the ability of cow's organism for protection against development of *mastitis*. Barkema *et al*. [1998] and Weiss [2002] inform on clearly advantageous association between the supplementation of cow's diet with microminerals, which can be present in "coloured" salt-licks, and udder health.

Factors that appeared to be significantly associated with the level of TMC in milk are presented in Table 2. Compared to factors correlated to SCC level, fewer factors were related to the level of TMC (7 *vs.* 10 factors, respectively). It is also noticeable that statistical significance of the relationships found was generally smaller ($p \leq 0.05$ in each case).

Contrary to SCC, the TMC is affected both by the microbiological status of the udder, as well as hygiene of milk harvesting and the pattern of milk handling until collection by the dairy enterprise. Therefore, most of the factors that were associated with TMC were not related to SCC in this study. Actually, only one factor (method of storing of the milking cluster between milkings) was related in the same pattern to both parameters.

Two factors characterising youngstock rearing, *i.e*. system of colostrum feeding to the newborn calf and system of replacement heifer rearing, were significantly associated with TMC level. Low TMC level was observed in the farms in which colostrum was fed by bucket, and in those where heifers older than 3 months were housed individually. The literature does not provide information on the effect of the first factor. It seems that it is most likely that bucket feeding was associated with higher microbiological quality of milk than the natural system of colostrum intake because sucking is conducive to spreading the inflammation among udder quarters of the dam. Another possible mechanism could be that milking colostrum prior to feeding into bucket allows its visual inspection and therefore earlier identification of mastitic cows and their appropriate treatment. It is stressed [Goff & Kimura, 2002; Weiss, 2002; Robert *et al*., 2006] that the onset of lactation appears to be a period of extremely large risk for contracting *mastitis* because of significant decrease in resistance of cows to infectious diseases.

Similar relationship between the system of rearing of replacement heifers older than 3 months and hygienic quality of milk was found in the study of Skrzypek [2002], who concluded that it was a result of positive (*i.e*. advantageous) effect of the individual system of housing on cytological quality of milk produced by the same animals during the productive period of life. This author claims that a key element of this relationship is intersucking observed in group-reared heifers, as the probability of such behaviour significantly increases after reaching the age of 3–4 months.

The pipe-line system of milking (*vs*. bucket system) was associated with the production of low TMC milk. Skrzypek [2003, 2006] found identical relationship and presented a view that it was caused by the fact that pipeline system minimizes the contact of the milked milk with external environment at all stages of the way between the udder and the tank in which it is stored.

Likewise in the case of SCC, storing milking clusters dry between milkings preceded by their cleaning and disinfection was associated with lower TMC compared to dipping in pure water or water containing a disinfectant. A discussion on the topic in question is presented earlier in this chapter.

Pre-milking udder and teat cleaning using a wet towel soaked with a disinfectant appeared to be the best method for production of milk with low level of TMC, as compared to other methods (washing with pure water or water containing a disinfectant). This observation is in agreement with results of numerous authors [Skrzypek & Kujawa-Kroll, 2002; Kamieniecki *et al*., 2004; Magnusson *et al*., 2006; Skrzypek, 2006], who claim that high microbiological quality of the milk of cows whose udder and teats are cleaned prior to milking using no water or very small amounts of water (wiping) result from the fact that this routine prevents from the transfer of microorganisms from the whole udder to the teat end and consequently to the harvested milk.

All low TMC farms used tank system of milk cooling and storage, whereas part of elevated TMC farms (6.6%) used a bucket system. Skrzypek [2003] and van Schaik *et al.* [2005] also found a positive effect of tank system on the microbiological quality of milk compared to the bucket system. The reason for advantage of the tank system is obvious, as this system enables a very quick decrease of milk temperature after milking to the desired level and minimises the contact of milk with the external environment.

Another factor associated with low TMC level in milk was regular calculation of feeding rations for cows. It can be expected that this effect acted through the association between the level of energy in feed and udder health. Namely, Faye *et al.* [1997], Suriyasathaporn *et al.* [2000] and Goff & Kimura [2002] found that both insufficient and excessive energy intake increased the frequency of clinical mastitis and elevated the level of SCC in milk.

CONCLUSIONS

1. Milk with low levels of somatic cells and microorganisms was produced in a minority of the investigated farms.

2. The following factors were associated with low level of somatic cells in milk: small herd size, tie-stall system of cow housing, grazing cows, regular use of advisory service, use of antibiotics at cow dry-off, post-milking teat dipping, regular use of California Mastitis Test, treatment of clinical cases of *mastitis* with antibiotics in selected cows only, and use of whole straw and salt-licks containing microminerals in cow feeding.

3. Factors associated with low level of microorganisms in milk were: large herd size, colostrum feeding to the newborn calf by bucket, individual housing of replacement heifers older than 3 months, pipe-line system of milking, pre-milking udder and teat cleaning with wet towel soaked with a disinfectant, tank system of milk cooling and storage after milking, regular calculation of feeding rations for cows.

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CZYNNIKI ZWIĄZANE Z POZIOMEM KOMÓREK SOMATYCZNYCH I DROBNOUSTROJÓW W MLEKU ZBIORCZYM

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Celem badań była analiza zależności między czynnikami charakteryzującymi zarządzanie stadem krów a poziomem komórek somatycznych (LKS) i ogólnej liczby drobnoustrojów (OLD) w mleku zbiorczym. Badania przeprowadzono w roku 2005 w 187 gospodarstwach rodzinnych, o wielkości stada krów od 6 do 60 sztuk, usytuowanych w sąsiadujących częściach Warmii i Mazur oraz Mazowsza. W oparciu o roczne średnie geometryczne, wszystkie gospodarstwa podzielono na gospodarstwa o niskim i podwyższonym poziomie LKS (<200.000 *vs*. 200.000 do 400.000 komórek/mL) oraz o niskim i podwyższonym poziomie OLD w mleku (<50.000 *vs*. 50.000–100.000 jtk/mL). W 55 gospodarstwach (29,4%) mleko charakteryzowało się niskim poziomem LKS, natomiast poziom OLD był niski w 65 gospodarstwach (34,8%).

Następujące czynniki były związane z niskim poziomem LKS: mała wielkość stada, uwiązowy system utrzymania krów, korzystanie z usług służby doradczej, stosowanie antybiotyków przy zasuszaniu krów, przechowywanie aparatów udojowych między dojami na sucho, poudojowa dezynfekcja strzyków, regularne stosowanie Terenowego Odczynu Komórkowego, leczenie klinicznych przypadków *mastitis* tylko u wybranych krów, stosowanie całej słomy w żywieniu krów oraz stosowanie lizawek zawierających mikroelementy (tab. 1).

Czynnikami związanymi z niskim poziomem OLD były: duża wielkość stada, karmienie nowonarodzonych cieląt siarą z wiadra, indywidualne utrzymanie jałówek reprodukcyjnych powyżej 3 miesięcy życia, rurociągowy system doju, przechowywanie aparatów udojowych między dojami na sucho, czyszczenie wymienia i strzyków przed dojem za pomocą ręcznika nasączonego środkiem dezynfekcyjnym, zbiornikowy system chłodzenia i magazynowania mleka po doju oraz regularne kalkulowanie dawek pokarmowych dla krów (tab. 2).