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Research Article

Associations between udder and skin cleanliness and somatic cell counts, yield, and composition of the milk of Polish Holstein-Friesian Black-and-White cows in autumn and winter

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SUMMARY

The aim of this study was to determine the associations between the cleanliness of the udder and skin of the hind part of the body and somatic cell counts in milk, milk yield, and milk composition in Polish Holstein-Friesian Black-and-White cows in autumn and winter. During test-day milking in the milking parlour a visual inspection of each animal was performed to evaluate the cleanliness of the udder, underbelly, tail base, upper hind limbs, and lower hind limbs. Soiling on the skin with faeces in each analysed part of the cow's body had a significant effect on the somatic cell count in the milk. The results of the study indicate that among the body parts analysed, the cleanliness status of the hind quarters of the udder had the greatest influence on the SCC in milk. In addition, increased soiling of the skin of the underbelly, tail base, and upper and lower parts of the hind limbs significantly reduced the contents of protein, casein, and dry matter in milk.

KEY WORDS: dairy cows, skin cleanliness, somatic cell count (SCC) in milk, yield and composition of milk, autumn/winter season

INTRODUCTION

When animal welfare deteriorates, the accumulated effect of stress factors may lead to the development of diseases and thus to a reduction in production. Methods for evaluating animal welfare are based on the use of objective and subjective indicators. The latter include behavioural observations, which reveal an animal's individual reactions to environmental conditions. In the case of cattle, an important element of management that is indicative of the level of animal welfare is the cleanliness of the skin. Research results show that the comfort of cows, hygiene in housing

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facilities, and control over cows' hygiene significantly affect milk quality, and for this reason should be the subject of studies on farm management practices (Sant'anna et al., 2011; Hauge et al., 2012; Erdem and Okuyucu, 2019). The cleanliness of dairy cows may be linked to the health status of the udder. The quality of raw milk is influenced by several factors, including the animals' health, correctly performed milking procedures, and the hygiene and condition of milking equipment (Arefeh et al., 2021). Deficiencies of micro- and macroelements in the feed ration lead to reduced activity of immune cells or dysfunction of the innate defence mechanisms of the teat, which in turn promotes the development of mastitis (Libera et al., 2021).

The consequences of mastitis in cows, which are commonly known, lead to considerable economic losses for farms (Huijps et al., 2008; Hogeveen et al., 2011; Geary et al., 2012). It is commonly assumed that mastitis reduces milk yield and milk quality. However, the adverse links between inflammation of the udder and reproduction in cows must be considered as well. A study by Smulski et al. (2020) showed that cows with mastitis in the first 100 days after parturition had poorer reproductive parameters (voluntary waiting period, calving interval, and insemination index). To determine the health status of the udder, Bobbo et al. (2020) proposed using the somatic cell count (SCC) and the ratio of the combined neutrophil and lymphocyte count (DSCC) to the total SCC in milk. This facilitates identification of healthy animals (those with low SCC and DSCC), cows susceptible to mastitis (those in which an immune response has been initiated, with an increase in DSCC, but not yet in total SCC), animals with ongoing mastitis (high SCC and DSCC) and animals with potential chronic mastitis (high SCC but low DSCC). One of the factors potentially limiting the development of inflammatory conditions in the udder may be improvement in the cleanliness of individual body parts, owing to appropriate herd management decisions. The scoring system used to evaluate the cow's cleanliness status is repeatable and is a useful practice for controlling mastitis (Ellis et al., 2007). Erdem and Okuyucu (2019) showed dependencies between the hygienic condition of the udder and teats and the SCC level in milk and milk composition. That study was conducted in the summer. In autumn and winter, however, it is more difficult to maintain cleanliness in animals. For this reason we conducted an analysis during this period. We postulated that there are dependencies between the hygiene status of individual parts of the udder and hind quarters of the body and the SCC and characteristics of milk.

The aim of the study was to determine the associations between the cleanliness of the udder and skin of the hind part of the body and somatic cell counts in milk, milk yield, and milk composition in Polish Holstein-Friesian Black-and-White cows in the autumn and winter.

MATERIAL AND METHODS

The study was conducted on a private farm keeping Polish Holstein-Friesian Black-and-White cows. Observations were made in the autumn and winter period from 20 October 2017 to 21 March 2018 and covered 201 cows, including 65 in their first lactation, 41 in the second, 42 in the third, 23 in the fourth and 30 in the fifth or later.

The experimental animals were kept in a free-stall cubicle barn with shallow litter bedding and with access to an outdoor run throughout the year. The entire run had a hardened surface and was partially roofed (approx. 1/3 of its area, adjacent to the barn). In the roofed part the floor of the run was regularly covered with barley straw, which was completely replaced with fresh straw once a week. The cubicle length and width as well as the area of the barn and the run per cow met the requirements for cattle management imposed by the Regulation of the Minister of Agriculture and Rural Development of 28 June 2010. Faeces from the barn aisles were removed once daily using a bulldozer. Barn beds were supplied with barley straw, which was replaced on a weekly basis.

Cows were milked twice a day in a DeLaval herringbone milking parlour (2 x 5 units). During the period analysed the mean milk yield per cow in a 305-day lactation was approx. 8 900 kg of milk with 4,06% fat content and 3,48% protein content. The average daily milk yield was 25,6 kg with 4,10% fat content and 3,59% protein content and an average SCC of 657 000/ml.

Feed rations for cows were standardized using the INRA method. The feed ration composition was identical for the entire herd and was balanced for daily milk yield of 25-26 kg. Feed was administered in a total mixed ration (TMR) containing the following feeds: maize silage, lucerne silage, sugar beet pulp, rapeseed meal, soybean meal, crushed wheat meal, and mineral and vitamin additives. The all-mash ration was administered twice a day after morning and evening milking.

Once a month during test-day milking in the milking parlour, visual inspection of each animal was performed (by the same person) to evaluate the skin cleanliness of the udder and the hind parts of the body. The skin soiling assessment method proposed by Pelzer (2008) was used, as modified at the Department of Cattle Breeding and Milk Production, Poznań University of Life Sciences. The evaluation was conducted according to the scheme given in Table 1.

Table 1

Skin inspection of the udder and hind body parts of cows – body parts and description

Body part	Description of area
1. Udder – lateral view	Side of the udder with its base and teats
2. Udder – back view (caudal side of udder)	Hind udder quarters, hind base, and teats
3. Underbelly	Underbelly from the udder towards the cranium
4. Tail base	Area around the tail base, within the radius from the middle of the tail to the vaginal vestibule
5. Upper part of hind limb	Area from the vaginal vestibule to the hock
6. Lower part of hind limb	Part of the limb below the hock, including hooves

Each body part was evaluated using a scoring system based on the percentage of soiling on the skin of the body part, as shown in Table 2.

Table 2

Scores for skin soiling of body parts

Area of soiling on skin of body part (%)	Score
≤ 2	1
>2 - ≤ 10	2
>10 - ≤ 25	3
> 25 - ≤ 60	4
> 60	5

Soiling of the skin was defined as moist or dry bovine faeces adhering to the skin. In the case of the udder in the lateral view, tail base, upper part of the hind limbs, and lower part of the hind limbs, both the left and right flanks were evaluated and the mean from both observations was calculated.

Data concerning daily milk yields, milk composition and somatic cell counts were collected from RW-2 performance records in Performance Tests of Dairy and Dual-purpose Cattle. A total of 959 data records were used for the statistical calculations. The actual SCC in milk was transformed to the natural logarithm according to Ali and Shook (1980).

The results were subjected to statistical analysis using SAS® (2019) ver. 9.4 software. The statistical methods were used to determine the associations between the cleanliness of the udder and skin of the hind body parts and the somatic cell counts in milk, milk yield and milk composition in Polish Holstein-Friesian Black-and-White cows in the autumn and winter.

The effect of the experimental factors was estimated by multivariate analysis of variance using the GLM– SAS® (2019) procedures, based on the following linear model:

$$y_{\mathrm{ijklmno}} = \mu + s_i + l_j + g_k + \beta_1 my_1 + \beta_2 dl_m + \beta_3 scc_n + e_{\mathrm{ijklmno}},$$

where:

$y_{ijklmno}$ – phenotypic value of trait
μ – population mean
s_i – fixed effect of season (i = 1, 2, 3)
l_j – fixed effect of lactation group (k = 1, 2, 3, 4, 5)
g_k – fixed effect of skin soiling score (n = 1, 2, 3, 4, 5)
β_1, β_2, β_3 – first-order partial linear regression coefficients
my_l – fixed effect of daily milk yield
dl_m – fixed effect of day of lactation
scc_n – fixed effect of somatic cell count
$e_{ijklmno}$ – sampling error

Spearman's correlations between soiling on the skin of the analysed body parts and SCC, milk yield, and milk composition were estimated using the CORR - SAS® procedure (2019).

Statistically non-significant effects were eliminated from the linear model, and the calculations were repeated. Detailed comparisons of means were made using Tukey's test.

RESULTS

Table 3 presents results concerning the association of faeces soiling on the skin in the udder (left and right sides) with the somatic cell count and composition of milk. The statistical analysis showed that the level of udder skin soiling assessed laterally had a significant effect ($P \leq 0{,}05$) on the actual and logarithmic SCC and on the protein content in milk. The actual and logarithmic SCC increased with the area of skin soiling on the left and right parts of the udder, while the protein concentration in milk decreased. However, cows with an udder skin soiling score of 1–3 assessed laterally (max. 25 % soiled udder area) did not differ in these parameters. The statistical analysis showed that cows with lateral udder skin soiling exceeding 25% produced milk with significantly higher actual and logarithmic SCC levels than cows with a lower degree of soiling on the skin of this body part. The milk of cows with the smallest area of lateral udder skin soiling (≤ 2%) had the highest protein concentration, which differed significantly from its concentration in the milk of cows with a faeces-soiled area > 25%.

For the hind part of the udder (Table 4) it was found that the degree of skin soiling had a significant effect ($P \leq 0{,}05$) on the actual and logarithmic SCC in milk. Milk collected from cows with a soiled area in the hind part of the udder amounting to max. 10% had significantly lower actual and logarithmic somatic cell counts than milk from animals with a greater area soiled with faeces on this part of the udder.

As the degree of skin soiling with faeces on the underbelly (Table 5) and the tail area (Table 6) increased, the actual and logarithmic SCC increased, while the contents of protein, casein and dry matter in the milk decreased. Cows with an underbelly skin soiling score from 1 to 3 (soiling up to 25%) or 4 or 5 (soiling above 25%) and a tail area soiling score from 1 to 4 (soiling up to 60%) did not differ in actual or logarithmic somatic cell counts in milk. In the case of animals with an underbelly skin soiling score within the range of 2 to 5 (soiling level over 2%) or from 2 to 4 points (soiling area > 2 - ≤ 60 %), no statistically significant differences were found between the means for protein, casein or dry matter content in milk (Table 5). The milk of cows with the greatest area of tail skin soiling (over 60%) had significantly lower concentrations of protein, casein, and dry matter than the milk of cows with the smallest area of skin soiling on this part of the body (max. 2%) (Table 6).

Table 3

Associations between the degree of skin soiling of the udder (left and right sides) and somatic cell count, daily yield, and composition of milk of Polish Holstein-Friesian Black-and-White cows

Trait	Skin soiling on udder – left and right side (score)										F	Effects in linear model					
	1 *N=150*		2 *N=431*		3 *N=291*		4 *N=75*		5 *N=12*			s_i	l_j	g_k	my_l	dl_m	scc_n
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		P-value					
SCC (10^3/ml)	500[a]	*725*	463[a]	*622*	806[ab]	*923*	1444[c]	*1054*	1047[bc]	*708*	17,50	0,2975	0,0001	0,0001	0,0065	0,4373	-
Ln (SCC)	12,38[a]	*1,18*	12,43[a]	*1,10*	12,94[a]	*1,21*	13,73[b]	*1,17*	13,60[b]	*0,81*	19,73	0,2729	0,0001	0,0001	0,0001	0,1488	-
Milk (kg)	24,6	*7,6*	25,8	*8,5*	25,8	*9,3*	25,4	*9,5*	24,8	*6,6*	48,03	0,0397	0,0006	0,5012	-	0,0001	0,0065
Fat (%)	4,17	*0,78*	4,15	*0,64*	4,05	*0,66*	3,88	*0,74*	4,06	*0,64*	14,85	0,0001	0,0292	0,6057	0,0001	0,6630	0,0001
Protein (%)	3,67[a]	*0,40*	3,59[ab]	*0,36*	3,60[ab]	*0,37*	3,47[b]	*0,42*	3,49[b]	*0,23*	36,37	0,0001	0,0001	0,0179	0,0001	0,0001	0,2547
Casein (%)	2,87	*0,33*	2,82	*0,30*	2,82	*0,32*	2,72	*0,27*	2,75	*0,17*	31,79	0,0026	0,0001	0,0583	0,0001	0,0001	0,1664
Lactose (%)	4,68	*0,35*	4,72	*0,26*	4,69	*0,23*	4,61	*0,28*	4,64	*0,24*	25,62	0,0653	0,0001	0,4902	0,0003	0,0001	0,0001
Dry mass (%)	13,36	*1,13*	13,24	*0,96*	13,17	*0,96*	12,78	*0,91*	12,98	*0,70*	20,61	0,0001	0,0013	0,3402	0,0001	0,0029	0,0001

Means denoted with different letters (in rows) differ statistically significantly: a, b, c - ($P \leq 0,05$)

Table 4

Associations between the degree of skin soiling on the caudal side of the udder and somatic cell count, daily yield, and composition of milk of Polish Holstein-Friesian Black-and-White cows

Trait	Skin soiling on caudal side of udder (score)										F	Effects in linear model					
	1		2		3		4		5			s_i	l_j	g_k	my_l	dl_m	scc_n
	N=176		*N=457*		*N=243*		*N=71*		*N=12*								
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		P-value					
SCC (10^3/ml)	473[a]	*723*	469[a]	*647*	907[b]	*923*	1380[c]	*1069*	1193[bc]	*838*	17,73	0,6156	0,0001	0,0001	0,0116	0,6901	-
Ln (SCC)	12,27[a]	*1,24*	12,46[a]	*1,06*	13,13[b]	*1,18*	13,64[b]	*1,23*	13,68[b]	*0,91*	21,29	0,7738	0,0001	0,0001	0,0001	0,3067	-
Milk (kg)	25,7	*8,0*	25,8	*8,4*	25,5	*9,1*	24,1	*10,1*	24,8	*9,3*	47,78	0,0337	0,0004	0,8111	-	0,0001	0,0116
Fat (%)	4,16	*0,77*	4,15	*0,63*	3,99	*0,67*	3,98	*0,71*	4,09	*0,85*	14,99	0,0001	0,0254	0,3892	0,0001	0,6141	0,0001
Protein (%)	3,62	*0,40*	3,61	*0,35*	3,56	*0,39*	3,55	*0,28*	3,65	*0,31*	35,66	0,0001	0,0001	0,1894	0,0001	0,0001	0,2319
Casein (%)	2,84	*0,33*	2,82	*0,29*	2,80	*0,34*	2,79	*0,25*	2,89	*0,30*	31,27	0,0023	0,0001	0,3234	0,0001	0,0001	0,0982
Lactose (%)	4,69	*0,37*	4,73	*0,23*	4,67	*0,24*	4,61	*0,28*	4,56	*0,22*	25,27	0,0639	0,0001	0,1594	0,0003	0,0001	0,0001
Dry mass (%)	13,30	*1,13*	13,27	*0,93*	13,08	*1,00*	12,92	*0,90*	12,86	*0,82*	20,51	0,0001	0,0011	0,4736	0,0001	0,0024	0,0001

Means denoted with different letters (in rows) differ statistically significantly: a, b, c - ($P \leq 0,05$)

Table 5

Associations between the degree of skin soiling on the underbelly and somatic cell count, daily yield, and composition of milk of Polish Holstein-Friesian Black-and-White cows

Trait	Skin soiling on underbelly (score)										F	Effects in linear model					
	1		2		3		4		5			s_i	l_j	g_k	my_l	dl_m	scc_n
	N=29		*N=185*		*N=439*		*N=194*		*N=112*								
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		P-value					
SCC (10^3/ml)	534[a]	*651*	419[a]	*582*	521[a]	*686*	986[b]	*1030*	1043[b]	*1005*	15,32	0,2486	0,0001	0,0001	0,0065	0,5630	-
Ln (SCC)	12,63[a]	*1,05*	12,27[a]	*1,16*	12,55[a]	*1,11*	13,14[b]	*1,26*	13,23[b]	*1,27*	17,36	0,2900	0,0001	0,0001	0,0001	0,2479	-
Milk (kg)	23,6	*6,9*	25,5	*8,2*	25,9	*8,8*	25,4	*9,1*	25,2	*8,7*	48,16	0,0472	0,0007	0,3675	-	0,0001	0,0065
Fat (%)	4,32	*0,72*	4,14	*0,67*	4,13	*0,68*	4,07	*0,62*	3,91	*0,74*	15,45	0,0001	0,0352	0,0659	0,0001	0,6364	0,0001
Protein (%)	3,75[a]	*0,45*	3,63[ab]	*0,39*	3,59[b]	*0,36*	3,61[b]	*0,36*	3,51[b]	*0,33*	36,45	0,0001	0,0001	0,0132	0,0001	0,0001	0,1469
Casein (%)	2,94[a]	*0,38*	2,84[ab]	*0,32*	2,82[b]	*0,30*	2,83[b]	*0,34*	2,74[b]	*0,24*	32,31	0,0016	0,0001	0,0089	0,0001	0,0001	0,0944
Lactose (%)	4,72	*0,19*	4,69	*0,38*	4,72	*0,21*	4,67	*0,25*	4,64	*0,27*	26,07	0,0659	0,0001	0,1121	0,0004	0,0001	0,0001
Dry mass (%)	13,69[a]	*1,33*	13,31[b]	*1,00*	13,22[b]	*0,96*	13,15[bc]	*0,97*	12,88[c]	*0,92*	21,72	0,0001	0,0021	0,0048	0,0001	0,0020	0,0001

Means denoted with different letters (in rows) differ statistically significantly: a, b, c - ($P \leq 0{,}05$)

Table 6

Associations between the degree of skin soiling on the tail base and somatic cell count, daily yield, and composition of milk of Polish Holstein-Friesian Black-and-White cows

Trait	Skin soiling on tail base (score)											Effects in linear model					
	1		2		3		4		5		F	s_i	l_j	g_k	my_l	dl_m	scc_n
	N=5		*N=23*		*N=367*		*N=342*		*N=222*								
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		P-value					
SCC (10^3/ml)	517[a]	*673*	416[a]	*427*	446[a]	*626*	581[ab]	*755*	1151[b]	*1034*	16,88	0,3162	0,0001	0,0001	0,0157	0,6366	-
Ln (SCC)	12,62[a]	*1,08*	12,42[a]	*1,08*	12,37[a]	*1,12*	12,62[a]	*1,15*	13,40[b]	*1,22*	19,10	0,4274	0,0001	0,0001	0,0022	0,2480	-
Milk (kg)	18,4	*5,2*	24,7	*8,7*	25,8	*8,3*	26,2	*8,4*	24,6	*9,6*	48,04	0,0393	0,0004	0,4891	-	0,0001	0,0157
Fat (%)	4,00	*0,58*	3,92	*0,72*	4,18	*0,70*	4,10	*0,65*	3,93	*0,67*	15,26	0,0001	0,0274	0,1434	0,0001	0,6486	0,0001
Protein (%)	3,84[a]	*0,52*	3,59[ab]	*0,42*	3,62[ab]	*0,32*	3,60[ab]	*0,35*	3,54[b]	*0,34*	36,59	0,0001	0,0001	0,0082	0,0001	0,0001	0,4382
Casein (%)	3,03[a]	*0,45*	2,83[ab]	*0,35*	2,84[ab]	*0,32*	2,82[ab]	*0,32*	2,77[b]	*0,27*	32,32	0,0014	0,0001	0,0085	0,0001	0,0001	0,3201
Lactose (%)	4,73	*0,06*	4,60	*0,62*	4,72	*0,28*	4,72	*0,19*	4,63	*0,27*	25,93	0,1198	0,0001	0,1795	0,0003	0,0001	0,0001
Dry mass (%)	13,50[a]	*1,24*	13,07[ab]	*0,98*	13,34[a]	*1,01*	13,24[a]	*0,95*	12,91[b]	*0,95*	21,84	0,0001	0,0015	0,0028	0,0001	0,0027	0,0001

Means denoted with different letters (in rows) differ statistically significantly: a, b, c - ($P \leq 0{,}05$)

The level of faeces soiling on the skin of the upper (Table 7) and lower (Table 8) parts of the hind limbs significantly influenced the SCC and composition of milk. Milk from cows with the greatest degree of skin soiling in the upper (Table 7) and lower (Table 8) parts of the hind limbs had the highest actual and logarithmic SCC. Milk from animals with the lowest degree of hind limb skin soiling (upper and lower parts) had the highest concentrations of protein, casein, and dry matter (Tables 7 and 8). Moreover, cows with the least soiled lower hind limbs were found to produce milk with the highest fat content (Table 8). The lactose concentration in milk was lowest in the group of cows with the lowest degree of soiling on the upper part of the hind limbs (Table 7). No clear dependencies were observed between the level of skin soiling with faeces on the lower parts of the hind limbs and lactose content in milk (Table 8). The correlation coefficients indicate a moderate correlation between the traits (Table 9). The strongest dependence ($r = 0,3359$) was noted between soiling on the skin on the hind part of the udder and the somatic cell count in milk. Correlation coefficients between skin soiling of individual parts of the udder and hind body parts and milk composition were negative and low, although most of them were statistically significant.

Table 7

Associations between the degree of skin soiling on the upper part of the hind legs (left and right sides) and somatic cell count, daily yield, and composition of milk of Polish Holstein-Friesian Black-and-White cows

Trait	Skin soiling on upper part of hind legs – left and right sides (score)										F	Effects in linear model					
	1		2		3		4		5			s_i	l_j	g_k	my_l	dl_m	scc_n
	N=15		*N=87*		*N=401*		*N=288*		*N=168*								
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		P-value					
SCC (10^3/ml)	680[ab]	*788*	461[a]	*657*	510[a]	*685*	721[ab]	*882*	999[b]	*991*	11,59	0,2583	0,0001	0,0001	0,0060	0,4971	-
Ln (SCC)	12,90[ab]	*1,07*	12,32[a]	*1,20*	12,50[a]	*1,12*	12,78[ab]	*1,24*	13,19[b]	*1,26*	14,38	0,3290	0,0001	0,0001	0,0001	0,1844	-
Milk (kg)	22,0	*8,4*	24,6	*7,9*	25,8	*8,6*	25,8	*8,8*	25,4	*9,0*	48,00	0,0525	0,0007	0,5356	-	0,0001	0,0060
Fat (%)	4,17	*0,78*	4,09	*0,69*	4,16	*0,68*	4,08	*0,69*	3,97	*0,64*	15,07	0,0001	0,0281	0,2917	0,0001	0,6937	0,0001
Protein (%)	3,74[a]	*0,49*	3,63[ab]	*0,43*	3,62[ab]	*0,36*	3,59[ab]	*0,36*	3,52[b]	*0,34*	36,24	0,0001	0,0001	0,0276	0,0001	0,0001	0,1790
Casein (%)	2,94[a]	*0,42*	2,84[ab]	*0,33*	2,84[ab]	*0,30*	2,81[ab]	*0,33*	2,75[b]	*0,26*	32,10	0,0012	0,0001	0,0190	0,0001	0,0001	0,1254
Lactose (%)	4,34[a]	*0,73*	4,69[b]	*0,41*	4,71[b]	*0,22*	4,72[b]	*0,21*	4,65[b]	*0,28*	29,87	0,1699	0,0001	0,0001	0,0006	0,0001	0,0001
Dry mass (%)	13,34[a]	*1,23*	13,29[a]	*1,10*	13,30[a]	*0,99*	13,19[a]	*0,96*	12,91[b]	*0,90*	21,21	0,0001	0,0018	0,0377	0,0001	0,0034	0,0001

Means denoted with different letters (in rows) differ statistically significantly: a, b, c - ($P \leq 0,05$)

Table 8

Associations between the degree of skin soiling on the lower part of the hind legs (left and right sides) and somatic cell count, daily yield, and composition of milk of Polish Holstein-Friesian Black-and-White cows

Trait	Skin soiling on the lower part of the hind legs - left and right sides (score)										F	Effects in linear model					
	1		2		3		4		5			s_i	l_j	g_k	my_l	dl_m	scc_n
	N=4		*N=9*		*N=173*		*N=517*		*N=256*								
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		P-value					
SCC (10^3/ml)	377^{a}	*126*	737^{b}	*538*	482^{a}	*600*	566^{a}	*775*	960^{b}	*984*	11,44	0,5348	0,0001	0,0001	0,0026	0,7569	-
Ln (SCC)	12,78^{a}	*0,42*	13,21^{b}	*0,89*	12,54^{a}	*1,04*	12,52^{a}	*1,21*	13,14^{b}	*1,24*	14,75	0,2697	0,0001	0,0001	0,0001	0,3781	-
Milk (kg)	18,1	*3,2*	26,8	*9,8*	25,2	*8,1*	25,8	*8,5*	25,4	*9,4*	47,96	0,0216	0,0006	0,5774	-	0,0001	0,0026
Fat (%)	4,85^{a}	*0,49*	4,01^{b}	*0,58*	4,26^{ab}	*0,72*	4,10^{b}	*0,66*	3,98^{b}	*0,67*	15,76	0,0001	0,0119	0,0184	0,0001	0,6765	0,0001
Protein (%)	4,04^{a}	*0,23*	3,59^{b}	*0,32*	3,68^{b}	*0,40*	3,60^{b}	*0,35*	3,53^{b}	*0,36*	37,60	0,0001	0,0001	0,0002	0,0001	0,0001	0,2346
Casein (%)	3,21^{a}	*0,23*	2,81^{b}	*0,24*	2,88^{b}	*0,33*	2,82^{b}	*0,31*	2,76^{b}	*0,29*	33,32	0,0097	0,0001	0,0002	0,0001	0,0001	0,1667
Lactose (%)	4,66^{a}	*0,13*	4,52^{b}	*0,65*	4,69^{a}	*0,34*	4,72^{a}	*0,23*	4,66^{a}	*0,25*	26,29	0,0849	0,0001	0,0495	0,0002	0,0003	0,0001
Dry mass (%)	14,25^{a}	*0,60*	13,44^{ab}	*1,41*	13,48^{ab}	*1,06*	13,21^{b}	*0,97*	12,95^{b}	*0,91*	22,32	0,0001	0,0004	0,0004	0,0001	0,0032	0,0001

Means denoted with different letters (in rows) differ statistically significantly: a, b, c - ($P \leq 0,05$)

Table 9

Spearman's correlations between skin soiling on analysed body parts and somatic cell count, daily yield, and composition of milk of Polish Holstein-Friesian Black-and-White cows

Traits		Udder – lateral view	Caudal side of udder	Underbelly	Tail base	Upper part of hind limb	Lower part of hind limb	Total skin soiling score
SCC (10^3/ml)	r	0,2923	0,3359	0,2524	0,2928	0,2013	0,1679	0,3125
	p-value	*0,0001*	*0,0001*	*0,0001*	*0,0001*	*0,0001*	*0,0001*	*0,0001*
Milk (kg)	r	0,0243	-0,0309	0,0068	-0,0173	0,0252	0,0238	0,0047
	p-value	*0,4531*	*0,3398*	*0,8327*	*0,5932*	*0,4366*	*0,4627*	*0,8840*
Fat (%)	r	-0,1091	-0,1013	-0,1108	-0,0936	-0,0837	-0,1325	-0,1249
	p-value	0,0007	0,0017	0,0006	0,0037	0,0095	0,0001	0,0001
Protein (%)	r	-0,0891	-0,0528	-0,0778	-0,0766	-0,0899	-0,1261	-0,0969
	p-value	0,0058	0,1024	0,0160	0,0177	0,0053	0,0001	0,0027
Casein (%)	r	-0,0896	-0,0417	-0,0846	-0,0797	-0,0955	-0,1216	-0,0980
	p-value	0,0055	0,1967	0,0088	0,0136	0,0031	0,0002	0,0024
Lactose (%)	r	-0,1067	-0,1345	-0,1070	-0,1490	-0,0527	-0,0772	-0,1291
	p-value	*0,0009*	*0,0001*	*0,0009*	*0,0001*	*0,1030*	*0,0168*	*0,0001*
Dry mass (%)	r	-0,1054	-0,1064	-0,1219	-0,1272	-0,1133	-0,1703	-0,1473
	p-value	*0,0011*	*0,0010*	*0,0002*	*0,0001*	*0,0004*	*0,0001*	*0,0001*

DISCUSSION

In this study the actual and logarithmic somatic cell counts in milk were shown to be statistically significantly influenced by faeces soiling of the skin of the udder (left and right side and caudally), underbelly, tail base, upper part of the hind limbs (left and right sides) and lower part of the hind limbs (left and right sides). Skin soiling on the caudal part of the udder exceeding 25% of the evaluated area significantly distinguished this group from animals with less skin soiling on that body part in terms of somatic cell counts in milk. This may indicate that the cleanliness status of the caudal part of the udder is of greater importance than that of other parts. Reneau et al. (2005) suggested that the scoring system used to evaluate the hygiene status of animals is repeatable, accurate and easy to use; however, in that study only scores for skin soiling on the udder and hind limbs were significantly correlated with the somatic cell counts in milk. Schreiner and Ruegg (2003) reported that the SCC in milk increased linearly with the degree of udder soiling.

The standard of hygiene in the living environment of animals is a significant factor influencing the number of somatic cells in milk. Kelly et al. (2009) showed a relationship between a low SCC in milk and a high standard of hygiene in the barn and more frequent cleaning in the aisles, cubicles, and yards on the farm. On the farm analysed in the present study, the milk of cows had an elevated SCC, which influenced their overall production level and milk analysis indicators. Most likely, the increased SCC in milk was associated with inadequate cleaning of the entire facility where the animals were housed. According to Devries et al. (2011), hygiene of cows depends on the cleanliness of their environment and on the time they spend standing and lying down. Soiling of the skin of the hind limbs (upper part and sides) and the udder was linked to more time spent lying down (particularly when the cubicles were soiled). On the other hand, Bewley et al. (2010) showed that longer time spent lying down was associated with an increase in the body condition status of cows. The length of the lying-down periods was not investigated in this study, although the animals which spent the longest time lying down each day probably had the most soiled udders, underbelly, and hind legs. For this reason, the cleanliness of bedding would need to be improved by replacing it more frequently. In the opinion of Robles et al. (2021), stall cleanliness should be improved to optimize lying time and potentially reduce lameness. According to Dufour et al. (2011) and Watters et al. (2013), to reduce SCC in milk it is advisable to use techniques promoting a standing position in cows after milking and to use sand as bedding material. However, an excessively long standing period may cause changes in the soft tissues and increase the incidence of lameness (Galindo and Broom, 2000). To improve animal cleanliness, it is also recommended to increase the frequency of removal of soiled litter from the barn floor. A study by Magnusson et al. (2008) showed that a clean floor in the aisle of a free-stall barn had a positive effect on the cleanliness of the runs as well as the udders and teats of cows. According to Chen et al. (2017), moist soil on the runs, even in the absence of wind or rain, has a negative impact on the welfare of cattle. This highlights the importance of preventing the accumulation of mud, for example through rainwater drainage and manure management. Dohmen et al. (2010) found that the mean annual SCC in the milk of cows was positively associated with the percentage of animals which had dirty teats and thighs before milking. Neja et al. (2016) showed that the percentage of cows with subclinical and clinical mastitis increased as udder cleanliness decreased, especially in the free-standing system. Overall, the percentage of cows with clinical mastitis increased from 2,51% (clean cows) to 14,29% (dirty cows). A study by Islam et al. (2020) showed that the cleanliness of the teats was higher than that of other parts of the udder and the rear body parts of cows, most likely because only the teats were cleaned before milking.

When an elevated somatic cell count is recorded in milk, the next step should include tests to identify microorganisms causing mastitis. This is particularly important when starting treatment, but it is also crucial for the herd owner, as it helps to reduce sources of pathogens in the animals' living environment of the animals.

It should be stressed here that the SCC in milk is determined by the type of microorganisms causing mastitis. A study by Malinowski et al. (2006) showed that coagulase-negative staphylococci (CNS), *Staphylococcus aureus*, and *Streptococcus* spp. caused SCC in milk to increase from 200,000 to 2 million/ml. Samples containing over 2 million/ml somatic cells were infected mainly by CAMP-negative and CAMP-positive streptococci and gram-negative bacilli, while somatic cell counts exceeding 10 million/ml were associated with *Arcanobacterium pyogenes*, *Streptococcus agalactiae* and gram-negative bacteria. A study by Petzer et al. (2017) found that the highest SCC in the samples tested was caused by *Streptococcus dysgalactiae*, *Streptococcus agalactiae*, and *Streptococcus uberis*. However, it should be stressed that systemic symptoms of udder inflammation are typically more common in herds with a lower average SCC in milk (Bakema et al. 1998). In a study conducted in Canada by Olde Riekerink et al. (2008), milk of cows kept in stanchion barns was observed to contain higher counts of *Staphylococcus aureus*, *Streptococcus uberis*, coagulase-negative staphylococci and other streptococci compared to milk produced by animals kept in the free-stall system, whereas the milk of cows from the free-stall system contained more *Klebsiella* spp. and *E. coli*.

Devries et al. (2012) reported a greater probability of elevated SCC in milk from cows with lower milk yields and in multiparous cows. As a rule, the milk of cows with mastitis has lower contents of milk components, although the concentration of crude protein may occasionally increase due to an increased concentration of whey protein. Atasever and Stádník (2015) found a positive correlation between SCC and protein concentration in milk. In our study, lower contents of protein, casein and dry matter were recorded in milk collected from cows with greater soiling on the skin of the analysed parts**.** The results of this study may indicate that mastitis in the examined cows was most likely first initiated by infection with bacteria from the group of major pathogens or their toxins, which at a certain stage of infection (disturbances in the secretion of protein and casein) reduce the content of crude protein in milk. This may be caused by changes in the levels of acute phase proteins during the infection. Robichaud et al. (2019) showed that increased yearly corrected milk production was associated with reduced prevalence of cows with dirty flanks. Lactose is an important milk component whose low content has an adverse effect on the yield of milk products. A study by Alessio et al. (2021) found that a decrease in the lactose concentration was linked to increased SCC in milk. In our study, however, no specific changes in lactose content were observed in association with different somatic cell counts in milk. Nevertheless, it should be remembered that apart from genetic factors and mastitis, milk composition and quality may also be influenced by nutrition, welfare operations, the animal management system, access to pasture, season of the year, air temperature and humidity, the age of cows, and the stage of lactation.

The results of a study by Erdem and Okuyucu (2019) conducted in the summer indicate that the hygienic condition of cows is of key importance for the quality of raw milk. The concentrations of milk components (except for fat percentage) were shown to be influenced by the hygiene status of the udder, hind legs, and flanks. The authors stressed that soiling on the skin of the mammary gland is a significant factor in mastitis, so cows should not have dirty udders. The results of our study confirm these dependencies, while additionally indicating a stronger association between the cleanliness of the hind part of the udder and the somatic cell count in milk, as compared to other body parts. In this case, soiling of the skin on more than 10% of the surface of this part of the body resulted in a statistically significant increase in SCC in milk. It is likely that microorganisms colonizing this part of the udder soiled with faeces can more easily enter the mammary gland through the teat, causing inflammation. The results indicate that keeping the hind part of the udder clean is one of the critical factors in preventing mastitis in cows. Moreover, the results of the analyses in this study during the autumn and winter show that the cleanliness status of the underbelly, tail base, and upper and lower parts of the hind limbs also has a significant effect on SCC in milk and the contents of milk components. In future research on the associations between the degree of skin soiling and SCC in milk and milking performance traits of cows, we recommend the use of standardized procedures in the collection of source data, e.g. photographs of cows, and the use of specialized computer software to analyse the data with regard to skin soiling on the examined body parts.

CONCLUSIONS

Soiling of the skin with faeces on the udder (left and right sides and caudally), underbelly, tail base, upper part of the hind limbs (left and right sides) and lower part of hind limbs (left and right sides), observed in autumn and winter, was found to have a statistically significant effect on somatic cell counts in milk. The SCC in milk increased with the percentage of soiled area. To prevent the development of mastitis it is particularly important to keep the hind parts of the udder clean.

Increased soiling of the skin of the underbelly, tail base, and upper and lower parts of the hind limbs (left and right sides) significantly reduced the protein, casein, and dry matter contents in milk.

One of the most significant aspects of dairy cow herd management is maintenance of the animals' cleanliness, which promotes the health of the mammary gland and determines production of milk with higher contents of milk components.

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