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The relationship between dairy cow hygiene and somatic cell count in milk

A. C. Sant'Anna* and M. J. R. Paranhos da Costa†[1]
*Programa de Pós-graduação em Genética e Melhoramento Animal, Universidade Estadual Paulista, 14.884-900 Jaboticabal-SP, Brazil
†Grupo de Estudos e Pesquisas em Etologia e Ecologia Animal, Departamento de Zootecnia, 14.884-900 Jaboticabal-SP, Brazil

ABSTRACT

Corporal hygiene is an important indicator of welfare for dairy cows and is dependent on facilities, climate conditions, and the behavior of the animals. The objectives of this study were to describe how the hygiene conditions of dairy cows vary over time and to assess whether a relationship exists between hygiene and somatic cell count (SCC) in milk. Monthly hygiene evaluations were conducted on lactating cows in 2 dairy farms for 9 consecutive months, totaling 3,554 evaluations from 545 animals. Hygiene was measured using a 4-point scoring system (very clean, clean, dirty, and very dirty) for 4 areas of the animal's body (leg, flank, abdomen, and udder) and combining these scores to generate a composite cleanliness score. A total of 2,218 milk samples was analyzed from 404 cows to determine SCC and somatic cell linear scores (SCLS). Individual variation was observed in the hygiene of cows throughout the year, with the highest proportion of clean cows being observed in August and the lowest in January. In spite of this seasonal variation, approximately half (55.62%) of the cows displayed consistent cleanliness scores, with 45.86% of them remaining consistently clean (very clean or clean) and 9.76% remaining dirty (very dirty or dirty) over the course of the study. The very clean cows had the lowest SCLS, followed by the clean, dirty, and very dirty cows (no statistically significant differences were found between the latter 2 groups). The most critical months for cow hygiene were those with the greatest rainfall, when a reduction in the welfare of cows and higher SCC values were observed. The evaluation and control of dairy cow hygiene are useful in defining management strategies to reduce problems with milk and improve the welfare of the animals.

Key words: animal welfare, cleanliness score, mastitis, dairy cow

INTRODUCTION

The hygiene of dairy cows can be used as an indicator of animal welfare, as it provides information about the quality of life of the animals and the quality of the farm facilities (Hultgren and Bergsten, 2001; Welfare Quality Consortium, 2009). Most studies that have evaluated the hygiene of dairy cows were performed with animals housed in freestalls and confirmed that the cows' level of hygiene is an important indicator of their welfare and that it is influenced by the characteristics and conditions of the facilities where they are kept (Nielsen et al., 1997; Hultgren and Bergsten, 2001; Zdanowicz et al., 2004; Zurbrigg et al., 2005; De Palo et al., 2006). It was expected, therefore, that poor hygiene in cows would be associated with an increased occurrence of disease such as environmental mastitis (Schreiner and Ruegg, 2003).

The incidence of mastitis in herds is one of the main difficulties faced by dairy farmers, with a negative effect on the productivity of the herd and the welfare of the animals (Philpot and Nickerson, 1991). Mastitis results in an increased SCC in milk, a parameter that can be used as an indicator in the evaluation of udder health in a herd (Fregonesi and Leaver, 2001). Furthermore, SCC has been used for the evaluation of milk quality (Auldist et al., 1996; Schukken et al., 2003). Evidence exists that increased SCC is associated with qualitative and quantitative milk losses due to a decrease in milk production (Jones et al., 1984; Fetrow et al., 1988; Miller et al., 1993), reductions in the concentrations of fat, lactose, and casein (Auldist et al., 1995, 1996; Lindmark-Månsson et al., 2006), and a negative effect on the sensory quality of pasteurized milk (Ma et al., 2000).

Some management practices, such as the formation of groups with a high density of animals (Barkema et al., 1999), the poor cleaning of stalls, inadequate bedding (Schukken et al., 1990), a high moisture content of the litter (Hutton et al., 1990), a lack of hygiene in facilities for dry cows (Chassagne et al., 2005), and the use of natural bodies of water (such as ponds or lakes) for drinking (Barnouin et al., 2004), are associated with an increase in milk SCC. On the other hand, releasing the animals to pasture at night was associated with lower overall SCC values (Barkema et al., 1999).

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[1]Corresponding author: mpcosta@fcav.unesp.br

Despite the many studies addressing the effects of management practices on SCC, as reported previously, few focused on the relationship between an individual cow's body hygiene and milk quality, and all of them were carried out with cows kept indoors (Schreiner and Ruegg, 2003; Reneau et al., 2005). In addition, little information is available regarding individual variation in body cleanliness through the year and which parts of a cow's body would be a better indicator of hygiene as a risk factor for milk quality.

Therefore, the objectives of this study were to describe how the hygiene conditions of dairy cows vary over time and to analyze the effect of hygiene on SCC in milk from cows that are not housed in stalls.

MATERIALS AND METHODS

The study was carried out by evaluating lactating cows from the herds of 2 dairy farms located in northwestern Sao Paulo State, Brazil. The herds were composed of Holstein cows (purebred and crossbred).

Farm 1 had approximately 250 lactating cows and an average production of 18 kg of milk/cow per day from 2 milkings. Groups were formed with approximately 50 animals, depending on parity order, milk production, body condition score, and health (occurrence of mastitis and hoof disease). On this farm, depending on the time of year, lactating cows were confined in outdoor pens with 900 m^2 (around 18 m^2 per cow) cemented floors or were released to grass paddocks (ranging from 3,000 to 6,000 m^2, in a daily rotation) with natural shade between milking sessions and at night. The pens were scraped once a week during the rainy season (December, January, and February) and once a month during the dry season.

Farm 2 had approximately 130 lactating cows and an average production of 25 kg of milk/cow per day from 2 or 3 milking sessions per day, depending on the level of production. The cows were divided into 5 groups, with 30 animals on average (ranging from 13 to 50), depending on parity order, milk production, body condition score, and health (based on occurrence of mastitis and hoof problems). These groups were kept in total confinement in paddocks ranging in size from 5,000 to 11,220 m^2, resulting in an area of 300 m^2, on average, per cow. In these areas, grass availability was very low and therefore did not contribute to their nutrition. During the rainy season (December–February), the areas close to the feed bunks (approximately 4 m wide) in all paddocks were scraped once a month due to mud accumulation. All cows were fed a TMR consisting of corn silage and concentrate, distributed evenly over the length of the feed bunks. All cows had free access to shade (trees and sheds covered by 70% shade cloth).

Cleanliness Scores

The hygiene of the cows was evaluated during milking and was based on visual cleanliness scores adapted from Schreiner and Ruegg (2003) and from Fregonesi and Leaver (2001), by independently evaluating 4 areas of each animal's body: the legs (**L**), flanks (**F**), abdomen (**A**), and udder (**U**). The scores were defined as follows: 1 = entire area was clean, with no dirt; 2 = less than half of the area was covered by dirt; 3 = half or more of the area was covered by dirt; 4 = entire area was covered by a layer of dirt. When hygiene was not uniform between the right and left sides of the animal's body, the dirtier side was chosen for the evaluation.

The scores from each of the 4 areas evaluated were combined to yield a composite cleanliness score (**CS**) for each cow, as follows: very clean animal (**VC**) = score of 1 in at least one area of the body and score of 2 for the remaining areas; clean (**C**) = at least 2 areas of the body with a score of 2 and none with a score of 4; Dirty (**D**) = 2 or more areas with a score of 3, with a maximum of 1 area with a score of 2 and 2 areas with a score of 4; very dirty (**VD**) = 3 or more areas with a score of 4.

The assessments of individual body cleanliness were carried out once a month with all lactating cows on both farms from July 2007 to March 2008. A maximum of 9 (25.0%) and a minimum of 1 (4.4%) assessments per cow (median = 7 and mode = 9) were carried out, generating a data set that included 545 animals and 3,554 cleanliness scores (because cows were excluded from or included in the lactation lots during the study period).

In addition, the animals were classified into 3 categories, depending on the consistency with which they maintained their hygiene scores: 1 = "consistently clean," composed of cows with combined cleanliness scores of VC or C in 75% or more of the evaluations; 2 = "consistently dirty," composed of cows with cleanliness scores of D or VD in at least 75% of observations; and 3 = "inconsistent," composed of cows that had the same cleanliness score with a frequency below 75%. Only cows with 4 or more cleanliness evaluations were included in this data analysis.

Milk SCC

Milk SCC was used as an indicator of milk quality. Individual SCC analyses were performed 2 d after the cleanliness evaluations. Milk samples were collected once a month of all lactating cows in both herds, from July 2007 to March 2008. The number of milk samples per cow was variable (because cows were excluded from or included in the lactation lots during the study period), ranging from 1 (5.3%) to 9 (12.0% of the cows; median and mode = 6). The final data set was composed of 532 animals and 2,957 SCC samples. Due to technical problems, SCC were not performed during November, December, and March on farm 2.

The milk samples were then analyzed at the laboratory of the Clínica do Leite (Departamento de Zootecnia, ESALQ, USP, Piracicaba-SP, Brazil). Somatic cell counts were performed by flow cytometry using the Bentley Somacount 300 (Bentley Instruments Inc., Chaska, MN).

Statistical Analysis of Data

Variation of Cleanliness Scores Throughout the Year. The χ^2 test for independence was used to evaluate the association of percentages of composite cleanliness score with the months of the year in which the assessments were performed.

Associations Between Cleanliness Scores. The multiple correspondence analysis (**MCA**) method was used for an exploratory analysis of the association between the cleanliness scores of each body area evaluated separately (legs, flanks, abdomen, and udder) and the composite cleanliness score and the consistency with which the animals maintained hygiene. This method is routinely used for categorical data and produces a graphical representation of the lines and columns of a contingency table, enabling the graphical analysis of the existing relationships by reducing the dimensionality of the data set (Greenacre, 1984). The levels of the variables used are positioned in the charts according to the association or similarity between them. The total variation of the data are called inertia; it is separated in each axis of the chart, with axis 1, considered the main axis, conferring the most information (inertia), axis 2 being the second most important, and so forth. The relative contributions of each variable to the total inertia of the first 2 dimensions studied (axes 1 and 2) are estimated, and the variables with the greatest contribution to inertia (greater percentage) are the most important in the formation of the axis.

The MCA were performed independently with data from 2 months, August and January, as these were the periods with the greatest percentages of cows with VC + C and VD + D scores, respectively.

SCC Analysis. For the statistical analysis of SCC data, the absolute values were transformed into somatic cell linear scores (**SCLS**) by applying the following equation:

$$SCLS = [\log2\ (SCC/100{,}000)] + 3.$$

Logarithmic transformations are the most appropriate for SCC data because they yield normality and homogeneity of the variances, enabling the execution of statistical analysis taking into account the above assumptions (Ali and Shook, 1980). This analysis included 2,218 SCC measurements obtained from 404 lactating cows, with each cow observed once a month and for a maximum of 9 mo.

The SCLS analysis was performed with the REML method, using the following mathematical model:

$$Y_{ijklm} = \mu + cg_i + pord_j + dlac_k + hig_l + cow_{ijklm} + e_{ijklm},$$

where Y_{ijklm} = dependent variable (SCLS); μ = mean; cg_i = effect of the ith contemporary group (where i = 1 to 42); $pord_j$ = effect of the jth parity order (where j = 1 to 7); $dlac_k$ = effect of the kth duration of lactation category (where k = 1 to 12, including variation within cows); hig_l = effect of the lth cleanliness score (where l = 1 to 4); cow_{ijklm} = random effect of the mth cow, of the ith contemporary group, of the jth parity order, of the kth duration of lactation category, of the lth cleanliness score (n = 404); and e_{ijklm} = residual random effect of the mth cow, of the ith contemporary group, of the jth parity order, of the kth duration of lactation category, of the lth cleanliness score.

The contemporary group was defined based on the animal group, herd (farm), and year of parity, by means of the following equation:

$$CG = G + \{[(H \times 100) + YP] \times 10\},$$

where CG = contemporary group; H = herd (1 or 2); YP = year of parity (6, 7, or 8); and G = group (1 to 13).

For this study, the duration of lactation was counted, in months, by dividing the total number of days in lactation by 30, and 12 categories of duration of lactation (dlac) were defined. Animals with more than 360 d in lactation were excluded from the sampling. In addition, the covariance structure used was compound symmetry. The estimates of fixed effects and of variance were obtained with a mixed model (PROC MIXED of SAS, 2000; SAS Institute Inc., Cary, NC), using Tukey's test to compare adjusted means.

The above model was used to carry out 5 analyses taking into account the following independent variables: (1) composite cleanliness score, (2) leg cleanliness score, (3) flank cleanliness score, (4) abdomen cleanliness score, and (5) udder cleanliness score. The majority of the independent variables (contemporary group, parity order, duration of lactation, and cow) were included in the model only for adjustment purposes, to allow a better assessment of the association between the cleanliness score and the somatic cell linear score.

RESULTS

Variation of Cleanliness Scores Throughout the Year

The χ^2 test showed a significant relationship between the cleanliness scores and months ($\chi^2 = 5.28$, df = 24; $P < 0.01$), indicating that the percentage of composite cleanliness scores varied according to the month, when considering the entire study period (from July to March). Higher percentages of very clean (VC = 32.15%) and clean (C = 52.96%) cows were observed in August, and higher percentages of very dirty (VD = 23.39%) and dirty (D = 30.33%) cows were observed in January (Figure 1).

Of the 545 cows used in the hygiene evaluation, 471 were observed at least 4 times and 55.62% were categorized as consistent, having obtained the same cleanliness score in at least 75% of the observations. Overall, 45.86% of the cows were consistently clean (VC + C) and only 9.76% were consistently dirty (D + VD).

Associations Between Cleanliness Scores

For August data, the MCA identified 3 groupings between the variables in the first dimensions (axes 1 and 2) that, combined, explained 45.34% of the total inertia of the data (Figure 2). The values of the positive and negative contributions to inertia for each of the variables are described in Table 1. For January data, the graphical analysis also allowed the identification of 3 groups, similar to those found for August. The first 2 axes combined (Figure 3) explained 46.42% of the total inertia of the January data, whereas axis 1 explained 27.54% of the inertia. The values of positive and negative contributions to inertia for each of the variables are described in Table 2.

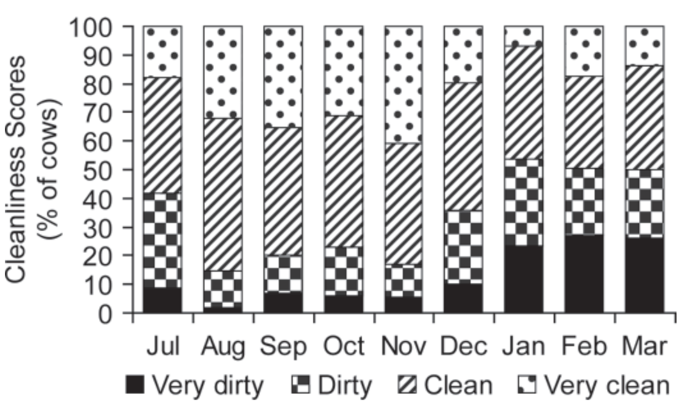

Figure 1. Proportion of cows in each of the cleanliness categories over the 9 mo of the study.

Based on the distribution of the variables along the first axis, 2 groups were identified for both months. Group 1 included "very dirty" variables (CS-4, U-4, A-4, L-4, and F-4), indicating the propensity of animals that have one area of the body entirely covered in a layer of dirt to have other parts of the body in the same condition of cleanliness. For January data, the "consistently dirty" variable was also included in this group. The greater proximity between the points observed for the rainy period suggested a stronger tendency for animals to have their entire bodies "very dirty." Group 2 included "very clean" (L-1, F-1, A-1, U-1, and CS-1) and "clean" variables (L-2), indicating a strong tendency for cows that had one of the areas of the body completely free of dirt to also have other areas of the body in the same condition, or to have, at most, a little bit of dirt on the leg (as characterized by a score of 2).

Axis 2 showed the greatest negative contribution to the variable representation of scores 2 (F-2, A-2, U-2, and CS-2) and 3 (L-3, F-3, A-3, U-3, and CS-3) and the greatest positive contribution to the variables described as groups 1 and 2 (as described in the previous paragraph). From this distribution, another group was evident in an intermediate position to groups 1 and 2, for both months, group 3, which included "clean" (F-2, A-2, U-2, and CS-2), "dirty" (L-3, F-3, A-3, U-3, and CS-3), and "inconsistent" variables. The characterization of this group indicated that the animals that got partially dirty showed greater variation in their cleanliness scores between body areas and greater variation over time. However, for January (rainy season), the "consistently clean" variable was also grouped.

Relationship Between Cow Hygiene and SCC

The averages (and respective standard deviations) of SCLS for each month of evaluation and for each farm are shown in Figure 4.

Significant effects were observed for all independent variables considered in the SCLS model (Table 3); these served to identify the sources of variation considered in the model (composite cleanliness score, contemporary group, parity order, and duration of lactation) as important factors in SCC variation. Similar results were observed when the analysis was conducted with the cleanliness scores for each body area, with each body area having significant effects on milk SCC when considered independently (leg: $F = 8.12$ and $P < 0.0001$; flank: $F = 5.66$ and $P = 0.0008$; abdomen: $F = 5.70$ and $P = 0.0008$; udder: $F = 6.28$ and $P = 0.0003$).

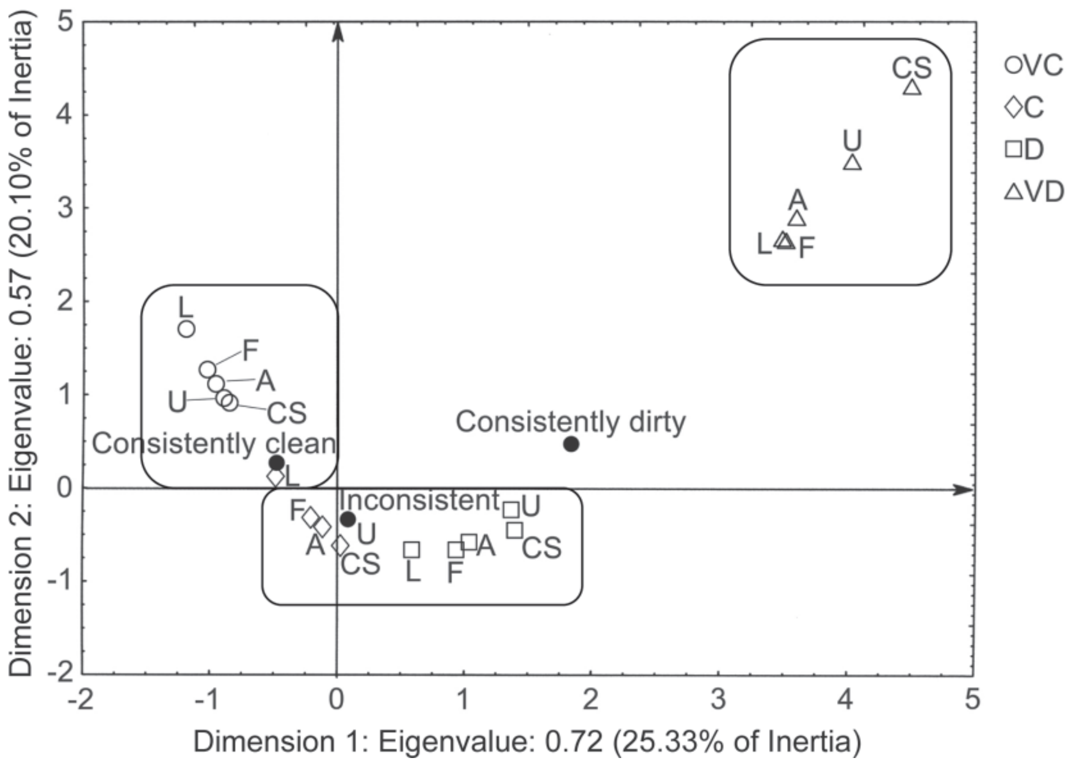

Figure 2. Perceptual multiple correspondence analysis map for August, relating the cleanliness scores for the 4 areas evaluated, composite cleanliness score, and hygiene consistency. CS = composite cleanliness score; F = flank; A = abdomen; L = leg; U = udder; VC = composite cleanliness score (CS) very clean or cleanliness score of 1; C = CS clean or score of 2; D = CS dirty or score of 3; and VD = CS very dirty or score of 4. (n = 379).

The SCLS means from each one of the hygiene categories, represented by the cleanliness scores for the leg, flank, abdomen, and udder, and the composite scores, were different; variations also existed in the significance of the scores in the MCA (Table 4). The SCLS did not differ between VC and C groups for the leg cleanliness variable, but for all of the remaining areas, the differences between the VC and C groups were significant ($P < 0.05$). In contrast, the cleanliness score of the leg did vary between groups D and VD, but no differences were found for the other body parts.

DISCUSSION

Variation of Cleanliness Scores Throughout the Year

During summer (January–March), a higher percentage of dirty and very dirty cows was observed. This phenomenon coincided with the period of higher rainfall, which resulted in a higher occurrence of mud in the facilities and negative effects on the cows' hygiene. This seasonal variation pattern, with lactating cows remaining cleaner during the winter, has also been observed in regions with a temperate climate (Ellis et al., 2007), confirming the importance of environmental factors as a source of hygiene problems for cows. However, a considerable number of cows remained consistently clean, even during the period of higher rainfall and with the accumulation of mud in the facilities where they were housed, indicating that certain behavioral patterns favored cleanliness (e.g., selecting dry and clean places to lie down). Future research to identify these behavioral patterns may be useful in identifying animals that are more likely to stay clean or dirty.

Associations Between Cleanliness Scores

The MCA found less distinction between cleanliness scores of 2 and 3 and greater distinction for both of the remaining scores. In practice, this could indicate that the characterization of half or more of an animal as dirty was not representative of the actual level of cleanliness. The major distinction in this analysis, however, was between animals "without dirt," "with dirt," and "with a layer of dirt." At this point, a simplification of the cleanliness score might be suggested to make it easier in terms of practical applicability. This tendency to simplify the cleanliness score was used in the development of the Welfare Quality protocol (Welfare Qual-

Table 1. Contributions related to the inertia of the multiple correspondence analysis for hygiene and dry season variables[1]

Axis X		Axis Y	
Positive contributions to inertia	Relative contribution to inertia (%)	Positive contributions to inertia	Relative contribution to inertia (%)
Flank 4	9.70	Composite score 4	9.96
Abdomen 4	9.51	Flank 1	8.38
Leg 4	8.98	Abdomen 1	8.23
Composite score 4	8.68	Composite score 1	8.23
Consistently dirty	7.44	Abdomen 4	7.62
Composite score 3	6.54	Udder 1	7.40
Udder 4	5.99	Flank 4	6.99
Udder 3	4.46	Leg 4	6.55
Flank 3	4.04	Udder 4	5.64
Abdomen 3	4.00	Leg 1	3.38
Leg 3	2.89	Consistently clean	0.82
Inconsistent	0.07	Consistently dirty	0.61
Udder 2	0.06	Leg 2	0.37
Composite score 2	0.01		
Negative contributions to inertia	Relative contribution to inertia (%)	Negative contributions to inertia	Relative contribution to inertia (%)
Composite score 1	5.84	Composite score 2	5.70
Udder 1	5.07	Leg 3	4.48
Abdomen 1	4.76	Udder 2	4.10
Flank 1	4.36	Abdomen 2	3.05
Leg 2	3.14	Flank 3	2.47
Consistently clean	2.42	Flank 2	1.80
Leg 1	1.30	Abdomen 3	1.66
Flank 2	0.57	Inconsistent	1.50
Abdomen 2	0.17	Composite score 3	0.87
		Udder 3	0.18

[1]Scores: 1 = composite score (CS) very clean or score of 1 for the body areas; 2 = CS clean or score of 2 for the body areas; 3 = CS dirty or score of 3 for the body areas; 4 = CS very dirty or score of 4 for the body areas.

ity Consortium, 2009) to evaluate the welfare of dairy cattle, which suggested the classification of a certain area as simply "clean" or "dirty."

Some peculiarities found when assessing the association of the cleanliness scores among the body parts in January could be attributed to the prevailing conditions in this month, which were characterized by the predominance of dirty and very dirty animals. In this case, group 1, classified as the most critical with respect to hygiene, included the variable "consistently dirty." This was not the case when considering data from August (dry season), suggesting that the environment was conducive to good hygiene, and even the "consistently dirty" animals were not scored as very dirty. Group 2, characterized as ideal from a hygiene perspective, did not included the animals classified as "consistently clean" in January, suggesting that in this period, characterized by environmentally dirty conditions, even the animals that were frequently clean were occasionally exposed to dirt.

In relation to the evaluated body parts, flank, udder, and abdomen showed the best agreement among each other and with the overall cleanliness score, as evidenced by the proximity of the points (Figure 2). The leg showed greater distinction from the other areas, as evidenced by the distancing of the leg variable from most groups. This result could be explained by the fact that this anatomical region of the body is more exposed to environmental dirt, especially when cows use paths with accumulated mud.

Hughes (2001) suggested that the variation between the different anatomical regions could provide useful information to help in the identification of the source of hygiene problems. According to this author, dirt on the legs results from high mud concentration and problems with paths, whereas a dirty tail would be associated with defecation and fecal matter, dirty flanks would reflect the state of the litter, and dirty udders and teats would result from the combination of all of these factors. According to our results, a high association of

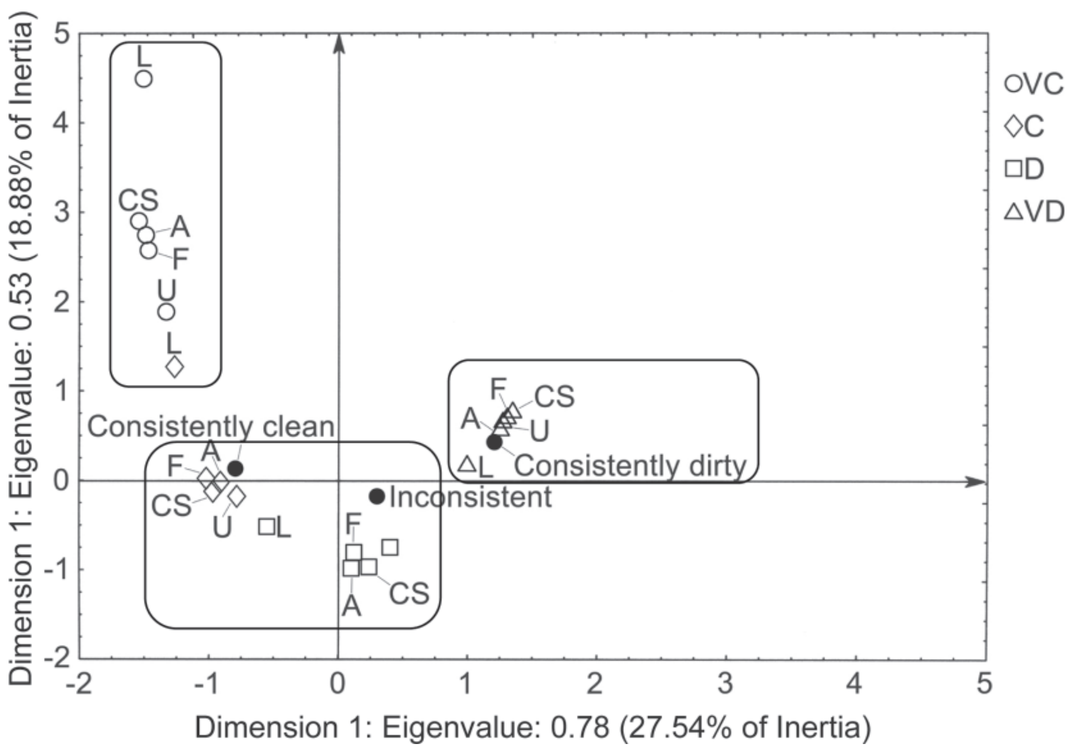

Figure 3. Perceptual multiple correspondence analysis map for January relating the cleanliness scores for the 4 areas evaluated, composite cleanliness score, and hygiene consistency. CS = composite cleanliness score; F = flank; A = abdomen; L = leg; U = udder; VC = composite cleanliness score (CS) very clean or cleanliness score of 1; C = CS clean or score of 2; D = CS dirty or score of 3; and VD = CS very dirty or score of 4. (n = 314).

cleanliness was observed between the different areas of the body evaluated, suggesting the potential to select one or a few body areas for the evaluation of cows' hygiene.

Poor hygiene is an indicator of problems in facilities and management, particularly milking management. Cows that have dirty udders require greater effort in terms of premilking sanitation. A high percentage of animals in this condition can influence both the time spent milking and the need for better-qualified employees who can execute the washing procedure correctly. In some cases, however, washing the teats is necessary but can increase the quantity of sediments in the milk (McKinnon et al., 1983) and compromise its quality.

Although poor hygiene conditions are more frequent and more intense during the rainy season, the existence of consistently dirty animals indicated that there were chronic cases of dirtiness. To avoid the occurrence of chronic hygiene problems, it is recommended that facilities be kept very clean, as evidence exists that animals look for places with moisture and feces to lie down, either for social reasons (Galindo and Broom, 2000) or because these places are softer and cooler (De Palo et al., 2006). Maintaining a consistently high percentage of clean animals requires inspection and frequent intervention in facilities and pathways, which is labor intensive but beneficial to both milk quality and work efficiency.

Relationship Between Cow Hygiene and SCC

The majority of the information available in the literature about cow hygiene associates the cleanliness of the animals with the cleanliness of the facilities and the occurrence of mastitis in animals housed indoors. Furthermore, the type and conditions of the facilities, in addition to management practices (Hutton et al., 1990; Barkema et al., 1999; Ellis et al., 2007), have significant effects on milk quality. These reports suggest a general effect on the entire group of animals, but, as indicated by our results, animals in the same group are under different types of pressures, exposing them unequally to the dirtiness of the environment. Unlike the studies cited above, Schreiner and Ruegg (2003) related the hygiene of the udder and the leg of each animal (and not the averages for the herd) with the occurrence of subclinical mastitis, as indicated by the presence of infectious mammary pathogens in milk and SCLS. A significant association was found between the cleanliness score of the udder and both indicators of ud-

Table 2. Contributions related to the inertia of the multiple correspondence analysis for hygiene and rainy season variables[1]

Axis X		Axis Y	
Positive contributions to inertia	Relative contribution to inertia (%)	Positive contributions to inertia	Relative contribution to inertia (%)
Composite score 4	10.13	Composite score 1	13.35
Abdomen 4	9.85	Flank 1	9.90
Flank 4	9.40	Abdomen 1	9.71
Leg 4	8.82	Udder 1	7.78
Udder 4	8.15	Leg 2	6.09
Consistently clean	3.28	Composite score 4	4.63
Inconsistent	1.02	Flank 4	3.84
Udder 3	0.98	Udder 4	3.22
Composite score 3	0.38	Abdomen 4	2.90
Flank 3	0.13	Leg 1	2.00
Abdomen 3	0.06	Consistently dirty	0.65
		Leg 4	0.39
		Consistently clean	0.23
		Leg 2	0.01
Negative contributions to inertia	Relative contribution to inertia (%)	Negative contributions to inertia	Relative contribution to inertia (%)
Composite score 2	7.18	Composite score 3	9.33
Flank 2	6.86	Abdomen 3	8.36
Abdomen 2	6.85	Flank 3	7.69
Udder 2	5.36	Udder 3	4.97
Consistently clean	4.93	Leg 3	3.85
Leg 2	4.12	Inconsistent	0.55
Leg 3	2.97	Udder 2	0.43
Udder 1	2.64	Composite score 2	0.12
Composite score 1	2.58	Abdomen 2	0.01
Flank 1	2.19		
Abdomen 1	1.96		
Leg 1	0.15		

[1]Scores: 1 = composite score (CS) very clean or score of 1 for the body areas; 2 = CS clean or score of 2 for the body areas; 3 = CS dirty or score of 3 for the body areas; 4 = CS very dirty or score of 4 for the body areas.

der health. The association of mastitis with cleanliness of the leg was lower than with that of the udder.

The relationship between cows' hygiene and SCLS was described by Reneau et al. (2005), using the same approach as in this study. Their approach used a more complex statistical method than that used by Schreiner and Ruegg (2003), with the application of a regression model that includes the effects of the herd, parity, and duration of lactation, in addition to hygiene effects. The authors also evaluated different areas of the body of the animal (tail insertion region, flank, abdomen, udder, legs, and a combination of udder and legs), finding a significant effect only for the udder, legs, and the combination of udder and legs. For each increase of 1 SD in these variables (SD = 0.84, 0.76, and 0.67, respectively), the SCLS increased by 0.13, 0.17, and 0.17, respectively.

In the present study, the effect of hygiene on the SCLS was compared using a statistical model that controlled the characteristics of individuals represented by the "cow" and the "group of contemporaries" variables (which included the herd, the group, and the year of parity), in addition to the duration of lactation (which also controls for variation within the individuals) and the number of lactations (as independent variables). With this type of analysis, it was possible to evaluate the role of the cows' hygiene in the variation in SCC, correcting for other sources of variation.

The results showed a significant effect for all of the body areas evaluated, which was expected due to the high degree of correlation between the cleanliness

Table 3. Analysis of variance summary of somatic cell linear scores (n = 2,218)

Effect	df	*F*	*P*-value
Contemporary group	41	5.60	<0.001
Cleanliness score	3	4.85	<0.01
Parity order	6	4.91	<0.01
Duration of lactation	11	13.59	<0.001

Table 4. Adjusted means of somatic cell linear scores (±SD) as a function of the composite cleanliness scores and of the cleanliness scores for each evaluated body area

	Dependent variable				
Level[1]	CS	Leg	Flank	Abdomen	Udder
VC	5.17 ± 0.23^{c}	4.92 ± 0.29^{c}	5.08 ± 0.23^{c}	5.08 ± 0.23^{c}	5.15 ± 0.23^{c}
C	5.40 ± 0.23^{b}	5.25 ± 0.22^{c}	5.41 ± 0.22^{b}	5.38 ± 0.22^{a}	5.37 ± 0.22^{b}
D	5.57 ± 0.24^{ab}	5.50 ± 0.22^{b}	5.55 ± 0.23^{ab}	5.59 ± 0.23^{b}	5.63 ± 0.24^{a}
VD	5.67 ± 0.25^{a}	5.78 ± 0.24^{a}	5.68 ± 0.25^{a}	5.63 ± 0.25^{ab}	5.71 ± 0.25^{a}

[a–c]Means within a column with a different superscript differ ($P < 0.05$).

[1]VC = composite cleanliness score (CS) very clean or cleanliness score of 1; C = CS clean or score of 2; D = CS dirty or score of 3; and VD = CS very dirty or score of 4.

scores for each body area and between these and the composite score. However, these results were different from some previous research, which revealed significant effects for only the udder and the leg (Schreiner and Ruegg, 2003; Reneau et al., 2005). These differences in results might be due to the evaluated groups having herds with different levels of SCLS and hygiene. It might also have been caused by the diversity of housing conditions, because animals housed in freestalls and tiestalls were kept under different environmental pressures than those animals housed in outdoor pens or at pasture.

When considering the practical applicability to the day-to-day activity of farms and focusing on the reduction of SCC in the herd, evaluation of cleanliness of the leg and udder alone would be sufficient. Furthermore, evaluation of only the leg and udder would be interesting because of the type of information that would be generated due to differences in anatomical regions and the implication of this effect on exposure to dirt. Consequently, the hygiene of the leg seemed to better differentiate SCLS for cleanliness scores that represented poor hygiene (3 and 4), whereas the cleanliness of the udder better differentiated scores representative of better hygiene (1 and 2). However, these 2 evaluations would still be complementary.

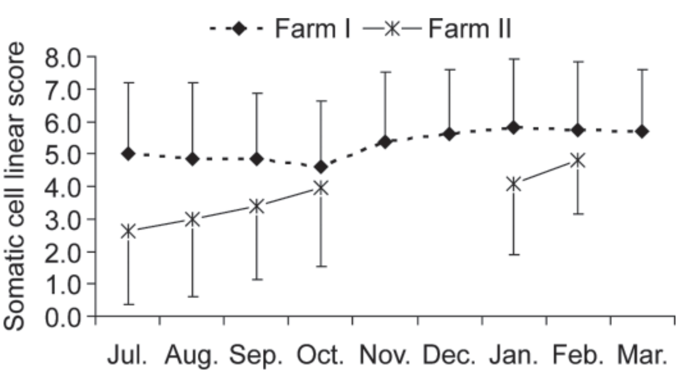

Figure 4. Means and standard deviations of somatic cell linear scores by farm and month.

A possible explanation for the association between dairy cow hygiene and SCC in milk would be the reduced exposure of clean animals to environmental pathogens. Another possibility would be the influence of poor cow hygiene with a lower efficiency for pre- and postdipping, which could result in an increase in incidence of contagious mastitis.

CONCLUSIONS

The most critical periods for the maintenance of hygiene in cows not housed in stalls are those with higher rainfall, as these periods result in greater difficulty in milking management and increases in milk SCC. Considering the economic losses due to high SCC and the increase in the risk of mastitis, the establishment of management procedures to control the hygiene of cows is recommended to reduce losses and improve the welfare of dairy cows. The first step is to evaluate the hygiene of cows, which can be done with the regular use of cleanliness scores. In practice, a cleanliness score can be used in a simpler version than that used in this study. The suggested method would apply only 3 scores: no dirtiness (very clean), presence of dirt, and presence of a layer of dirt (very dirty). Due to the association of cleanliness of the leg and udder with increases in the risk of udder disease, we recommend recording the presence of small quantities of dirt on the udder. For the legs, however, only in the case of a large accumulation of dirt would it be necessary to intervene, because these parameters presented the greatest risk to udder health in this study.

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