Risk factors associated with subclinical mastitis in dairy cows on Swiss organic and conventional production system farms

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ABSTRACT: Epidemiological studies comparing risk factors for subclinical mastitis (SM) in organic (OP) and conventional dairy production systems (CP) are lacking. In 60 OP and 60 CP farms, 970 cows were used to study risk factors for SM at 31 days postpartum. Cows showing a positive (≥ 1+) California Mastitis Test (CMT) in at least one quarter, but without clinical symptoms, were classified SM-positive. For OP cows increased ($P < 0.05$) odds ratios (OR) for SM were found for other than Simmental and Simmental × Red Holstein breeds, for increasing number (> 27) of cattle on the farm, for the use of mineral feed supplements, for irregular milking intervals (< 12 and > 12 h/day), and for milk urea concentrations of 210.1–270 mg/dl, whereas decreased OR for SM were recorded for cows kept in barns on beddings other than on rubber mats or concrete, for farms with rinsing water temperatures of milking systems between 54.75 and 60°C, for milk lactose > 50.5 g/l, and for blood albumin levels of ≥ 38.5 g/l. For cows on CP farms, increased ($P < 0.05$) OR for SM were found for other than Simmental × Red Holstein and Simmental breeds, for a bedding area width of > 117 cm, and for antibiotic mastitis treatment since the last dry period, whereas reduced ($P < 0.05$) OR for SM were found for farms with a moderate (in contrast to good) hygiene status and for routine application of antibiotics during the dry period. Observed differences between OP and CP were assumed to be partially related to system-specific management, such as antibiotic dry cow therapy, nutrition and milking routine.

Keywords: subclinical mastitis; organic farms; risk factors; cows

Subclinical mastitis (SM) accounts for high economic losses in dairy farms (Batra, 1986; Tyler et al., 1989). There is evidence, although not consistent, that SM is a more frequent problem in organic (OP) than in conventional production systems (CP) systems (Krutzinna et al., 1997; Weller and Davies, 1998; Busato et al., 2000; Fehlings and Deneke, 2000; Hovi and Roderick, 2000; Zwald et al., 2004; Roesch et al., 2006a,b). Impaired udder health as a cause of cow replacements was significantly (2.3 times) more important in OP than in CP farms (Roesch et al., 2006c). Our preceding studies (Roesch et al., 2005, 2006a,b,c) have shown that there were no significant differences in the prevalence of California Mastitis Test (CMT) positive samples between OP and CP at the cow level, but there were more CMT positive quarters in OP than CP farms. The somatic cell counts (SCC) in individual milk samples both from OP and CP cows were low, indicating a high udder health standard. However, the SCC were sig-

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nificantly higher in OP than CP cows between three to six weeks postpartum. The SCC and CMT data at the quarter level indicated that cows in OP farms mainly in early lactation have more problems in maintaining a good udder health than cows in CP farms. Approximately 25% of medium to severely affected quarters (CMT reactions ≥ 2+) and microbiologically analyzed milk samples were bacteriologically negative. With the exception of a higher frequency of non-agalactiae (other) streptococci in OP than CP cows, but a lower frequency of coagulase-negative staphylococci in OP than CP cows, no significant differences in the bacterial spectrum (such as *Staphylococcus aureus, Corynebacterium bovis, Escherichia coli*) between OP and CP cows were found. Restrictions in the use of antibiotics for prophylaxis against and treatment of udder infections (Krutzinna et al., 1997; Weller and Davies, 1998; Busato et al., 2000; Hertzberg et al., 2003; Zwald et al., 2004) may be causes for possibly increased SM in OP cows. However, the prevalence of SM is known to be influenced by many additional factors, such as husbandry, management, genetics, nutrition and associated metabolic and endocrine changes. Epidemiological studies on SM in OP in direct comparison with CP that screen for and evaluate risk factors for SM are to the best of our knowledge lacking. In sequence we have performed logistic regression analyses on risk factors associated with SM on both OP and CP farms using the data collected in our previously mentioned study (Roesch et al., 2005, 2006a,b,c) and compared the sets of identified risk factors for SM between the two farming systems.

MATERIAL AND METHODS

Data collection and selection of farms and cows

All study farms were located in the canton of Bern, Switzerland. Due to logistic limitations the original study was designed to include 120 farms and approximately 1 000 cows. The farm and animal selection process has been described in detail elsewhere (Roesch et al., 2005, 2006a,b,c). In short, 60 certified OP farms with at least three years of organic production were randomly selected out of a pool of OP farms within the canton of Bern, Switzerland. Then, 60 CP farms, again from a pool of farms, were selected on the basis of their geographic proximity (ZIP code), the same agricultural zone (altitude above sea level) and similar farm size (number of cows) when compared with the respective OP farms.

On each study farm, between 5 and 13 dairy cows (depending on herd size) were randomly selected. There were more Simmental × Red Holstein (SI × RH) cows on OP than on CP farms (266 and 239, respectively), whereas the number of pure-bred (red and black) Holstein (HO) cows was lower on OP than on CP farms (95 and 127, respectively). The number of pure-bred Simmental (SI; 91 and 94, respectively) and other breeds (Brown cattle, Montbéliard, Jersey; 31 and 27, respectively) did not differ between OP and CP farms. Ages of cows (medians: 5.3 and 5.2 years, with ranges 3.1–13.4 and 2.6-16.6 years) and lactation numbers of cows (medians: 4, with ranges 2–14) were similar between farm types.

In total, 483 OP and 487 CP cows in the study were tested for SM between 21–42 days (median 31 days) postpartum. Three to 15 visits per farm were necessary to collect the data from all cows at the planned lactation stage. Farm visits, performed by two graduate students, started in June 2002 and were completed in May 2003. For most cows, the visit took place in winter (December–February: *n* = 388), followed by fall (September–November: *n* = 294), spring (March–May: *n* = 214) and summer (June–August; *n* = 74), but there were no significant differences between farm types (Roesch et al., 2006b).

The CMT was done after udder sanitation, appraisal and discarding of foremilk at a quarter level. The CMT results were classified as 0+ (negative), 1+ (traces), 2+ (gel), and 3+ (clumps, highly viscous). Quarters with CMT ≥1+ were considered as subclinically inflamed. Current milk production data (milk yield and concentrations of fat, protein, lactose, and urea) from 958 cows were made available from the Swiss Simmental and Red and White Cattle Breeding Association, from the Swiss Brown Cattle Breeder Federation, and from the Swiss Holstein Breeding Association. We used the data of the official milk measurement that was closest in time to the day of our cow visit. In the rare case that the visit date was exactly between two measurement dates, the values of the measurement taken before the respective visit were used.

Blood samples were taken from the tail vein using evacuated tubes containing K_2-EDTA (9 g/l) as anticoagulant. The tubes were centrifuged at 1 000 × *g* for 20 min and plasma was stored in plastic tubes at –20°C.

In addition, farm management and cow husbandry data were collected, as shown in Table 1.

Laboratory procedures

Analyses of milk and blood that were used in the present study have been described in Roesch et al. (2005, 2006a,b,c).

Variables associated with the occurrence of subclinical mastitis

About 100 different variables (and their transformations) collected at the farm and at the individual cow level were evaluated for their association with the presence of SM (Table 1).

Data analysis

All described analyses and model building steps were performed separately for cows on OP and on CP farms. Descriptive statistics as well as basic univariable data analyses to check for the association between all factors of interest and the outcome status (SM positive) were performed according to Hosmer and Lemeshow (2000) and Dohoo et al. (2003) using MS Excel, NCSS 2001 (www.ncss.com) and STATA v7 (www.stata.com). For the identification of risk factors for SM, uni- and multivariable logistic regression models were developed and run within the stepwise (sw) logistic regression module of Stata.

The outcome of interest, SM at the individual cow level, was dichotomized: all cows that had at least one quarter with a positive (≥ 1+) CMT reaction, but no evidence of clinical mastitis, were

Table 1. Variables tested for association with subclinical mastitis in a study of 60 organic farms (OP) and 60 conventional dairy farms (CP) in the canton of Bern, Switzerland

Housing and farm management in general	loose or tie stall barn, tethering system in tie stall barns, length and width of cubicle, cow trainer, material of cubicle floor and kind of bedding, disposal of manure, hygiene of barn, income generated with farming, main farming activity (milk, fattening of calves, agriculture), number of cows, calves, heifers, breed(s), replacement, sending cows to alpine pasture in summer, time on pasture and paddock per day, annual milk quota, use of alternative veterinary methods, agricultural zone, and in OP farms the number of years they produced organically
Feeding	summer or winter feeding and performance of feed analyses
Milking procedures	hours between milking times, udder sanitation and stimulation, controlling, practice of stripping procedure, regularly performed post-milking teat dipping, frequency of California Mastitis Test performed per cow per month
Milking machine	kind of milking technique, performance of milking machine, vacuum level, number of clusters used, type and replacement rate of liners, sanitation of milking units
Milk production data	energy-corrected milk produced in preceding and in current lactation, somatic cell count of preceding lactation, milk composition (fat, protein, urea and lactose), persistency of preceding lactation, difference of individual energy-corrected milk yield relative to herd mean
Antibiotic medication of udder	antibiotic dry cow therapy, antibiotic treatment during the dry period, antibiotic treatment between calving and visit, antibiotic treatment at time of visit
Udder health	California Mastitis Test on quarter level, front or hind quarter, number of quarters with a positive (≥ 1+) California Mastitis Test reaction
Occurrence of diseases	birth complications, diseases of digestion, limbs and claws, metabolic diseases, udder diseases other than mastitis
Specific cow data	breed, age, parity, body condition score, weight, ease of milking, udder suspension, claw condition, consistency of feces
Blood traits	plasma concentrations of glucose, non-esterified fatty acids, β-hydroxybutyrate, urea, albumin, 3,5,3‘-triiodothyronine, insulin-like growth factor-1
Study design variables	days between calving and farm visit, month of sampling, season of sampling, time of sampling, CP or OP farm

defined as SM positive. For this analysis, all cows with clinical mastitis at the time of examination were excluded.

Cow-level interval-scale data were categorized into four levels based on quartiles, and subsequently analyzed as categorical variables since a true linear relationship between a continuously measured factor and the odds ratios (OR) for SM often could not be demonstrated. Preliminary analyses (results not shown) indicated that the relative importance of specific risk factors for SM differed between farm types. It therefore was decided to identify and discuss the factors associated with SM separately for OP and CP farms, thereby avoiding the need to consider farm matching and 2-way interactions between farm type and the respective risk factors in the analysis. The hierarchical data structure (clustering of cows within farms) still had to be accounted for. After classifying cows as SM positive or negative, the association between SM status and categorical farm- as well as cow-level variables was assessed using univariable logistic regression models with correction for farm-level clustering [STATA logistic, r cl (farm)]. Results were expressed as OR that indicate the chance (odds) that cows in the respective risk factor level would be SM positive when compared with the chance of cows in the baseline risk factor level. Categorical variables that resulted in an univariable logistic regression (LR) *P*-value < 0.10 in at least one of their levels were selected as potential candidates for the multivariable LR approach. Of those, all SCC-related variables were excluded from the multivariable approach since the CMT classification used to define SM is a proxy parameter for the respective SCC. These associations between SM and various SCC measurements were evaluated and presented separately. Also excluded from further analysis were all cow-level milk, blood and reproduction parameters that referred to the previous (rather than the current) lactation.

The remaining list of possible risk factors for SM within each farm type was screened, and variables with < 10 observations (cows) in one of the outcome categories were excluded from the multivariable analysis in order to avoid model conversion and estimation problems. A Spearman Rank correlation analysis was run on all remaining risk factors and on those variable pairs with a correlation > |0.6| identified. Of those pairs, only one variable was retained in order to avoid collinearity problems in the multivariable model.

The selected potential risk factors were then subjected to stepwise logistic regression approaches with hierarchical forward selection and hierarchical backward elimination, both with swapping (re-assessment of previously included or excluded variables). The *P*-values for data inclusion and exclusion were set at 0.05 and 0.075, respectively. Farm identity again was included as a cluster variable. All variables that had been selected or retained in those stepping approaches entered the final LR analysis (again with farm identity as a cluster variable), in which the final odds ratio estimates with 95% confidence intervals were derived. No additional confounders or 2-way and higher-level interaction terms were considered in this analysis. The level of statistical significance for all comparisons, when not otherwise indicated, was set to *P* < 0.05.

RESULTS

Risk factor analysis for subclinical mastitis

Of over 100 individual cow-level and farm-level risk factors that were evaluated for their association with SM (CMT ≥ 1), 12 were derivates of the SCC measurements routinely done on studied farms. These were analyzed separately and not further considered as "risk factors" in the multivariable LR approach. For those SCC-related variables, the univariable LR model with correction for clustering of cows within farms indicated that the odds for SM (CMT ≥ 1) increased with increasing SCC (data not shown). This association was strongest in the concurrent (to the CMT test) SCC measurement. In that evaluation, the odds for cows to be outcome (SM) positive was 27.5 (16.5–45.6) times greater in the highest SCC quartile when compared with cows in the lowest SCC quartile.

Both for CP and OP farms, 29 non-SCC-related variables had *P*-values < 0.1. After elimination of five variables in each group because of their high correlation, the remaining 24 entered the multivariable analysis.

In OP, six variables were included in the forward stepping approach, while 10 variables were retained in the backward elimination process (Table 2; columns FW and BW and legend). As further shown in Table 2, for cows in OP farms, increased (*P* < 0.05) OR for SM were found for cows being of other than Simmental × Red Holstein and pure Simmental breeds, for increasing number of cattle on the farm,

Table 2. Final multivariable association (odds ratios – OR, lower confidence limits – LCL, upper confidence limits – UCL; *P*-values) between current subclinical mastitis status (at least one quarter California Mastitis Test (CMT) ≥ 1+) and farm- as well as cow-level parameters in a study involving 483 cows held on 60 dairy farms with organic production (OP) located in the canton of Bern, Switzerland. Current measurements were done at a median of 31 days postpartum. Logistic regression model with adjustment for farm-level clustering of cows; all continuously measured variables were categorized based on quartiles. FW/BW (x) = variable initially selected by the forward and backward stepping approach ($P < 0.05$), respectively

Risk factor	Group	Selection process and final model results					*P*
		FW	BW	OR	LCL	UCL	
Cow breed	SI × RH			–			
	SI	x	x	1.034	0.496	2.157	0.928
	HO	x	x	1.744	0.911	3.339	0.093
	other	x	x	3.307	1.571	6.959	0.002
Number of heifers and cows on farm	< 20			–			
	20–22		x	1.415	0.687	2.915	0.346
	23–27		x	1.445	0.732	2.853	0.289
	> 27		x	2.243	1.121	4.487	0.002
Cows held on bedding other than rubber mat or concrete	no			–			
	yes	x	x	0.380	0.192	0.753	0.006
Use of mineral feed supplements	no			–			
	yes	x		2.173	1.179	4.007	0.013
Rinsing water temperature of milking system (°C)	< 54.75			–			
	54.75–60.0		x	0.485	0.269	0.874	0.016
	60.01–70.0		x	0.857	0.421	1.745	0.671
	> 70		x	0.715	0.356	1.435	0.345
Milking interval (h)	12/12			–			
	11/13		x	1.715	1.110	2.650	0.015
Milk lactose (g/l)	< 48.2			–			
	48.2		x	0.761	0.456	1.270	0.297
	49.3		x	0.789	0.433	1.440	0.440
	> 50.5		x	0.392	0.203	0.757	0.005
Milk urea (mg/l)	< 160			–			
	160–210		x	0.960	0.559	1.647	0.882
	210.1–270		x	1.768	0.941	3.324	0.007
	> 270		x	0.718	0.351	1.471	0.365
Plasma albumin (g/l)	< 38.5			–			
	38.5		x	0.492	0.272	0.892	0.020
	40.01		x	0.560	0.303	1.037	0.065
	> 41.5		x	0.456	0.233	0.889	0.021

Presence of a paddock, feeding routine and plasma 3,5,3-triiodothyronine concentrations were found as additional factors that were recognized in the step-wise selection model, but they are not shown because OR for subclinical mastitis were not significant ($P > 0.05$)

SI × RH = Simmental × Red Holstein; SI = pure Simmental; HO = (pure) red and black Holstein; other = Montbéliard, Jersey and Brown cattle for the use of mineral feed supplements, for irregular milking intervals (< 12 or > 12 h/day), and for milk urea concentrations of 210.1–270.0 mg/l. On the other hand, decreased OR for SM were recorded for cows held in barns on beddings other than rubber mats or concrete, for farms with water rinsing temperatures of milking systems between 54.75 and 60°C, for milk lactose > 50.5 g/l, and for blood albumin levels of ≥ 38.5 g/l. Several additional factors showed trend associations with the SM status.

In CP, eight variables were entered in the forward stepping approach, while 12 variables were retained in the backward elimination process (Table 3; columns FW and BW and legend). As further shown in Table 3, for cows in CP farms, increased (*P* < 0.05) OR for SM were found for cow breeds other than Simmental × Red Holstein and pure Simmental, for a bedding area width of > 117 cm, and for antibiotic mastitis treatment since the last dry period. Reduced (*P* < 0.05) SM odds were found for farms with a moderate (in contrast to good) hygiene status and for routine application of antibiotics at the start of the dry period.

DISCUSSION

The analysis of data set was complicated by the fact that in the original study design OP and CP farms were individually matched on geographic proximity, elevation and herd size, farm-type, and that the design was not specifically targeted at assessing risk factors for SM. Farm type as well as some of the design factors were possibly also associated with either the outcome (SM) or some potential risk factors investigated in the study. In addition, the data had a hierarchical structure with udder quarter-level, cow-level and herd-level infor-

Table 3. Final multivariable association (odds ratios – OR, lower confidence limits – LCL, upper confidence limits – UCL; *P*-values) between current subclinical mastitis status (at least one quarter California Mastitis Test (CMT) ≥ 1+) and farm- as well as cow-level parameters in a study involving 487 cows held on 60 dairy farms with conventional (integrated) production (CP) located in the canton of Bern, Switzerland. Current measurements were done at a median of 31 days postpartum. Logistic regression model with adjustment for farm-level clustering of cows; all continuously measured variables were categorized based on quartiles. FW/BW (x) = variable initially selected by the forward and backward stepping approach (*P* < 0.05), respectively

Risk factor	Group	Selection process and final model results					*P*
		FW	BW	OR	LCL	UCL	
Cow breed	SI × RH			–			
	SI	x	x	0.832	0.462	1.497	0.539
	HO	x	x	1.965	1.163	3.321	0.012
	other	x	x	4.210	1.804	9.823	0.001
Width of bedding area (cm)	< 110.5			–			
	110.5–115.0		x	1.372	0.886	2.122	0.156
	115.1–117.0		x	0.974	0.648	1.465	0.900
	> 117.0		x	2.894	1.352	6.199	0.006
Farm hygiene status	good			–			
	moderate		x	0.618	0.406	0.940	0.025
Routine use of antibiotics for dry cow udder treatment	no			–			
	yes	x	x	0.461	0.304	0.699	0.000
Antibiotic mastitis treatment since last dry period	no			–			
	yes	x	x	5.088	2.241	11 552	0.000

Number of cows on farm, number of breeds on farm, average age at first calving, dairy farming as main income, type of tethering, use of mineral feed supplements, and vacuum during milking were found as additional factors that were recognized in the step-wise selection model, but because OR for subclinical mastitis were not significant (*P* > 0.05)

SI × RH = Simmental × Red Holstein; SI = pure Simmental; HO = (pure) red and black Holstein; other = Montbéliard, Jersey and Brown cattle mation. In order to account for some of the clustering, quarter-level information was summarized per cow, thus eliminating this level in the hierarchical structure. By running two separate analyses on the association between SM and the selected risk factors we eliminated the problem of the influence of matching. In order to account for the cluster effect of multiple cows per herds, herd identity was always included into the analysis as a cluster variable. This approach, in STATA v7, produces robust (wider) variance estimates of the regression coefficients and therefore more robust (conservative) OR confidence intervals.

The breed was the only factor that was significantly associated with the risk for SM in both OP and CP. This indicated that this effect was independent of the farm type. Busato et al. (2000), too, showed that the category of "other breeds", containing predominantly Swiss Brown, a few Montbéliard and Jersey cattle, had the highest risk for SM. The difference between the breeds may be in part associated with udder conformation, genetic traits (Schukken et al., 1990), and with metabolic, endocrine and immunological differences.

A wide range of farm and animal level management factors can influence the odds for SM, as shown under Swiss husbandry conditions (Bielfeldt et al., 2004). This was obviously also the case in the present study.

Nutritional and associated metabolic factors, that are in part reflected by changes in the composition of milk, are well known to influence the occurrence of mastitis (Burvenich et al., 2003). In this respect the finding that high milk lactose levels (> 50.5 g/l) in OP are associated with a reduced risk for SM is interesting. Thus, because low milk lactose levels are a symptom of mastitis, high milk lactose would expectedly speak against SM. In addition, milk lactose levels can be increased at a high energy intake (Reist et al., 2003). If so, the increased risk for SM at lower lactose levels may have been associated with insufficient energy intake, possibly due to a smaller intake of concentrates in OP than CP cows in the actual study (Roesch et al., 2005) and may in part explain why OR for SM were significant only in OP but not in CP. Furthermore, relatively increased plasma albumin levels were associated with reduced OR for SM in OP, but not in CP. The blood albumin level is to some extent a mirror of the status of protein and energy intake of dairy cows (Clement et al., 1991; Reist et al., 2003). In this respect milk urea concentrations are also of interest because they are well known to be influenced by the intake of crude protein relative to intake of energy. In Swiss OP farms during the winter season the protein supply, based on milk protein and urea concentrations, seemed to be insufficient, as shown in an earlier study (Trachsel et al., 2000). In the present study, plasma albumin and urea concentrations and milk protein and urea concentrations were lower in OP than CP cows, indicating a reduced protein intake in OP, in part likely due to reduced intake of concentrates in OP than in CP (Roesch et al., 2005). However, in the present study, in OP the risk for SM was increased with milk urea concentrations of 210.1 mg/l (relative to lower or higher concentrations). This is hard to explain. It is also not obvious why a higher risk for SM in association with milk urea concentrations was only present in OP but not in CP. Also, there are no obvious explanations why the use of mineral supplements was associated with an enhanced risk for SM and why this was only true in OP but not in CP. One can only speculate that this was due to differences of the relative importance of the various factors in the two systems.

In OP the influence of an irregular interval between morning and evening milking (< 12 or > 12 h/day) on the prevalence of mastitis may have been the consequence of an enhanced chance for bacteria to colonize teat ends and streak canals during the longer milking intervals. The number of quarters with milk leaking is well known to increase with prolonged intervals between milkings. Leaking of milk has a significant effect on the occurrence of clinical mastitis (Schukken et al., 1990, 1991; Elbers et al., 1998) which is assumed to result in enhanced frequency of SM. Hamann (2001) reported that there is a significant change in SCC related to varying inter-milking intervals even in healthy udder quarters. Why this factor was only significant in OP, but not in CP farms is not evident, but may indicate that the milking routine was less strict in OP than CP. Reduced teat dipping in OP than CP may be an additional factor (Roesch et al., 2000c).

A close relationship between poor hygiene of barn or cow and high SCC can be expected and has been described elsewhere (Barkema et al., 1998; Schreiner and Ruegg, 2003). That this factor was only of importance in CP but not in OP farms and especially that a moderate relative to a good hygiene status was associated with a reduced risk for SM is, however, not obvious. The increased OR for

SM, if the number of heifers and cows on OP farms was > 27, may indicate that individual care of cows was greater if less cows were present. Possibly other management factors, that were associated with a greater risk for SM, were also contributing to this problem in OP relative to CP. However, we see no obvious explanations why factors, such as bedding other than rubber mats or concrete or rinsing water temperatures of the milking system were associated with SM only in OP, but not in CP farms.

Individual routine antibiotic dry cow therapy reduced the OR for SM only in CP, but not in OP cows. This may have been simply due to the fact that dry cow therapy in OP cows is basically forbidden. Antibiotic therapy at the end of lactation seems to be the most effective means to eliminate existing infections and to prevent new infections (Eberhart, 1986). A positive effect is seen mainly in infected udders with contagious pathogens, whereas environmental (streptococcal) infections may or may not be reduced at calving compared with drying off (Smith and Hogan, 1993). There was a much greater reduction in SCC from prepartum to postpartum periods on CP than on OP farms (results not shown). This was most likely due to the use of antibiotic dry cow therapy of CP cows.

Antibiotic udder treatment since calving in the present study was positively associated with the occurrence of SM, but only in CP cows. The elevated SCC may have resulted from damage to the mammary gland tissue, which only slowly regenerated even in the absence of infections. The therapy may have failed or cows may have become reinfected (Dohoo et al., 1984). In addition, quarters that had recovered from *Streptococcus uberis* or *Staphylococcus aureus* mastitis have a higher rate of new infection than quarters that have no history of previous infection (Zadoks et al., 2001). That there was only an association in CP, but not in OP cows may be an indication of the fact, that alternative medication rather than antibiotic treatment is more often applied in OP than CP.

In conclusion, the study shows that there are a number of different factors that are associated with the occurrence of SM in both OP and IP cows. Some of the factors were only significantly associated with enhanced odds for SM in OP farms, while others were only significantly associated with enhanced odds for SM in CP farms. While some of the factors can easily be explained, the explanations for other factors are not very obvious.

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