Performance of Dairy Cows on Swiss Farms with Organic and Integrated Production

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ABSTRACT

Milk production of cows on farms in which milk was organically produced (OP) tends to be less than that on farms with conventional or integrated production (IP), but causes for the difference have not been thoroughly evaluated. We performed a study to investigate management, nutritional, metabolic, and endocrine risk factors that may be associated with lower milk production on OP farms. Fertility traits were also compared. In 60 OP and 60 IP farms, matched in size, location, and agricultural zone (altitude), 970 cows were selected. Body condition scores (BCS) and body weights (BW) were determined at approximately 29 d prepartum (visit 1) and at 31 (visit 2) and 102 d postpartum (visit 3). Blood was sampled at visit 2 to determine plasma concentrations of glucose, nonesterified fatty acids, β -hydroxybutyrate, albumin, urea, insulin-like growth factor-1 (IGF-I), and 3,5,3'-triiodothyronine. Metabolic and endocrine traits as well as milk yield, fertility, and feeding factors were compared among cows in the 2 production systems. A univariable and stepwise multivariable logistic regression model was used to identify risk factors for poor milk yield. Energy-corrected milk yield medians and milk urea concentrations were less in OP than in IP cows at visits 2 and 3. Organic farms provided less concentrates, and OP cows at all visits had lower BW than IP cows. Plasma albumin and urea concentrations were lower in OP than IP cows. The following factors were positively associated with low milk yield (below median): Simmental breed, greater BCS, positive California mastitis test in hindquarters, and sampling during summer. Factors associated with an elevated (above median) milk yield were: Holstein breed, greater BW and lactation number (age), weak udder suspension, greater blood albumin, milk fat and milk protein, more lactation persistency, longer calving intervals, routine teat dipping, and more outdoor access

during winter. In conclusion, significant differences including milk yield were detected between Swiss OP and IP cows. Lower milk yields were due to a range of individual animal and farm-level factors such as breed, nutrition, management, and udder health.

(Key words: organic dairy production, milk yield, fertility, risk factor)

Abbreviation key: CMT = California mastitis test; ECM = energy-corrected milk; IGF-1 = insulin-like growth factor-1; IP = integrated production; OP = organic production; OR = odds ratio; range_p = percentile ranges; T₃ = 3,5,3'-triiodothyronine.

INTRODUCTION

Milk yields of cows on farms with organic production (OP) have been reported to be lower than on farms with conventional or integrated production (IP; Krutzinna et al., 1996; Kristensen and Kristensen, 1998; Byström et al., 2002; Hamilton et al., 2002). Reasons for lower milk yield in OP herds may be due to differences in genetics, management, and feeding, and a greater prevalence of subclinical mastitis (Augstburger et al., 1988; Busato et al., 2000; Hovi et al., 2002). In addition to differences in feeding and milk yield, effects of production type on reproductive performance can be expected. Based on a decree for Swiss organic dairy production (Anonymous, 1997), cows should be fed to allow the production of high quality rather than high quantities of milk. Consequently, relatively poor yields on OP farms are thought to result partly from reduced amounts of concentrates fed (Trachsel et al., 2000; Thuen et al., 2002). In spite of relatively poor production, it was suggested that cows with better genetic potential for milk production on OP farms may be at a greater risk of energy deficiencies in early lactation and may experience more metabolic disorders and poorer fertility than cows on conventional farms (Lund and Algers, 2003). Comparative studies on milk production on OP and IP farms are limited and results may differ from country to country. Large-scale epidemiological studies are lacking. The objective of the present study was to determine management, nutritional, metabolic,

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and endocrine factors that impact milk production and fertility in Swiss cows on OP farms when compared with cows on IP farms.

MATERIALS AND METHODS

Study Design and Selection of Farms and Cows

All farms in the study were located in the canton of Bern, Switzerland. The canton of Bern was selected because of its geographical diversity (midland, hill, and alpine regions) and because it has a particularly large number of OP farms. Only farms that had at least 5 dairy cows, a milk quota >10,000 kg/yr, and regular (monthly) milk control (kilograms produced, contents, SCC) performed by the breeding organizations were included so that sufficient data on milk performance and milk composition were available. All OP farms had to be certified by BioSwiss (Frick, Switzerland), and had to have practiced organic farming for ≥ 3 yr. Farms that converted from conventional to organic farming during the last 3 yr were excluded.

All registered OP farms ($n = 707$) that met the inclusion criteria were asked to participate in the study and 26% agreed. A roster of all IP farms in the canton of Bern including herd size, milk quota, and farm location was obtained from the Federal Office of Agriculture, Bern, Switzerland. To each of the remaining 180 OP farms, 4 IP farms were matched such that: 1) they were in the same or adjacent community; 2) the number of dairy cows was similar (allowed difference: ≤ 2 cows); and 3) the farms were situated in the same altitude category above sea level (3 zones). Of the 720 contacted IP farms, 141 (20%) agreed to participate in the study.

Of the volunteering OP and IP farms, 105 OP-IP pairs were identified that matched the above criteria. Due to resources, the study had to be limited to 60 farm pairs. Based on the distribution of all OP farms with an annual milk quota > 10,000 kg in the different zones of canton of Bern, 13 pairs from the midland/prealpine zone, 34 pairs from mountain zones I and II, and 13 pairs from mountain zones III and IV were selected by stratified random sampling (MS-Excel random number generator). In a second selection step, approximately 1000 dairy cows with ≥ 2 lactations (to have data from a preceding lactation) were selected randomly based on farm size. All cows were examined 3 times, with target times being 30 d prepartum (visit 1), 30 d postpartum (visit 2), and 100 d postpartum (visit 3).

Data and Sample Collection

During visit 1 (target: 30 d prepartum), nutrition, general management, housing, annual milk quota, herd health management, and fertility data of the preceding

lactation were collected using semiclosed questionnaires and standardized examination protocols. A health form was left with the farmer to record the occurrence of diseases.

It also was recorded whether farmers performed teat dipping and California mastitis tests (CMT) once a month or more often, and if appraisal and discarding of foremilk was performed before milking. Time that cows spent in an exercise yard (<1, ~1, or >1 h/d) during winter was recorded.

At each of the 3 visits, amounts and type(s) of concentrates and forages fed were recorded. Concentrates included grains, commercial concentrates, and protein supplements. Amounts of provided protein supplements were calculated separately. Information on the amounts of concentrates fed on different farms was based on feeding plans, on-farm weighing, and additional information provided by the farmer. Summer feeding consisted mainly of grass supplemented with extra dry feed, and (or) succulent feed when cows were kept on pasture. Winter feeding consisted mainly of corn and grass silage together with hay or grass silage and hay or silage-free forage for raw milk cheese production. As feeding management varied greatly between farms, summer roughage feeding data were categorized into 3 groups: grass only; grass and dry feed; grass, dry feed, and succulent feed. Winter feeding was categorized into 4 groups: 1) dry feed, grass, and corn silage; 2) dry feed and grass silage; 3) silage-free feed; and 4) other feeding regimens. Summer feeding began when cows were maintained solely on pasture and ended when cows were moved permanently into barns (free stall, tie stall, or stanchions). This varied mainly with altitude above sea level.

The BW of cows was estimated using a tape at each farm visit (Aeberhard et al., 2001b). In addition, the BCS was determined based on a 5-point scale from 1 (lean) to 5 (fat) with 0.25-point increments (Edmonson et al., 1989).

Blood samples (20 mL) were collected from the tail vein of each cow during the second farm visit (target: 30 d postpartum) using evacuated tubes containing EDTA (1.8 g/L of blood). Samples were kept on ice for 15 min after collection and then centrifuged at $1000 \times g$ for 20 min. Plasma was harvested and stored frozen in plastic tubes at -20°C until analyzed.

The CMT was performed on milk from each quarter after udder cleaning, appraisal, and discarding of foremilk during the second and third farm visits (targets: 30 and 100 d postpartum). The CMT results were interpreted as 0+ (negative), 1+ (trace), 2+ (gel), and 3+ (clumps). Quarters with CMT $\geq 1+$, but without clinical signs of mastitis, were considered subclinically infected (Roesch, 2004). Udder suspension was evaluated as

good (teat tip at the level of the hock), mediocre (udder floor at the level of the hock), or poor (teat tip and udder floor below the hock).

Energy-corrected milk (ECM) yields and milk composition (fat, protein, lactose, and urea concentrations), lactation persistency (calculated as percentage change in kilograms of ECM), and SCC for the preceding and the current lactation were supplied by the 3 Swiss breeding organizations (Schweizerischer Fleckviehzuchtverband, Zollikofen; Schweizerischer Holsteinzuchtverband, Grangeneuve-Posieux; Schweizerischer Braunviehzuchtverband, Zug). Data from official milk measurements that were closest in time to the dates of the farm visit were used. If the visit was equidistant between the 2 measurements, values of the second measurement were used. The ECM (based on 3.14 MJ of NE_L/kg) was calculated from concentrations of fat and protein in milk as $ECM = \{[0.383 \times (\text{fat } \%) + 0.242 \times (\text{protein } \%) + 0.7832] \div 3.14\}$ (Misciattelli et al., 2003). Measurements of lactose were not included in the calculation of ECM yields because they were not available from all farms.

Fertility data were supplied by the 3 Swiss breeding organizations cited above. Days between parturitions (calving interval) and from parturition to first insemination (waiting period) were calculated.

Laboratory Procedures

Plasma concentrations of BHBA were measured photometrically with a kit (catalog no. RB 1007) from Randox Laboratories (Antrim, UK). Plasma concentrations of glucose, albumin, and urea were measured using kits (catalog nos. 61269, 61051, and 61974, respectively) from BioMérieux (Marcy l'Etoile, France), and plasma concentrations of NEFA were determined with a kit (catalog no. 994-75409) from WAKO Chemicals (Neuss, Germany) with a selective analyzer (Cobas Mira 2, Hoffmann La-Roche, Basel, Switzerland). Concentrations of insulin-like growth factor-1 (IGF-I) and 3, 5, 3'-triiodothyronine (T₃) in plasma were determined by radioimmunoassay as described by Blum et al. (2000). Coefficients of variation within and between assays for albumin, BHBA, glucose, NEFA, and urea were <2 and 3%, respectively, and for IGF-I and T₃ were <10 and 15%, and <8 and 12%, respectively.

Milk samples were stored at approximately 5°C after collection, and analyzed within 24 h. Standard procedures according to the Guidelines of the International Dairy Federation were applied for bacteriological examinations. Somatic cell counts were determined by a fluoro-opto-electronic method (Fossomatic 250, Foss Electric, Hillerød, Denmark).

Variables Associated with the Probability of Poor Milk Yield

To identify factors associated with poor milk yield, 2 groups of cows (low- and high-yielding) were defined based on the median ECM yield during the preceding lactation (≤ 305 d) of all investigated cows.

A range of management- and farm-associated and individual cow variables collected during farm visits were first tested for their univariable association with milk yield. The variables found to be significant were then submitted to a multivariable logistic regression procedure (described below). The measures investigated are described below.

Housing and farm management. Loose housing or tie stalls, type of fixation in tie-stall barns, length and width of stall, cow trainer, flooring material in stall and kind of bedding, disposal of manure, hygiene of barn, income generated from farming, main farming activity (dairy, fattening of calves, agriculture), number of cows, calves and heifers, breed(s), replacement, grazing on alpine pastures during summer, time spent on pasture (summer) and in exercise yard (winter) per day, annual milk quota, use of alternative veterinary medicine, agricultural zone (altitude above sea level), and years since conversion to organic farming (OP farms).

Feeding. Type of forage, succulent feed and mineral supplement, amount and type of concentrates and summer or winter feeding, start of planned feeding preparatum, whether dry cows were fed separately, allocation of concentrates according to performance, automatic feeding of concentrates, feeding of a TMR, and percentage of purchased forage and concentrates.

Milking procedures. Milking interval, udder stimulation, discarding of foremilk, milking-out procedure, teat dipping, and performance of regular CMT. Milking machine: milking technique, technical data on milking machine, vacuum, replacement, and hygiene of milking units.

Milk production data. Milk composition (fat, protein, urea, and lactose) during the lactation preceding our study and at the second and third farm visits, persistency, and SCC during the preceding lactation.

Antibiotic medication of the udder. Dry-cow therapy and antibiotic treatments, udder health, and results of CMT ≥ 1 for each quarter.

Occurrence of diseases. Dystocia, diseases of digestion, limbs, claws, metabolic diseases, and udder diseases other than mastitis.

Specific cow data. Breeds, age, lactation number, BCS, BW, milkability, udder suspension, claw condition, and consistency of feces.

Blood parameters. Plasma concentrations of glucose, NEFA, BHBA, urea, albumin, T₃, and IGF-I.

Variables out of study design. Days between calving and farm visit, month of sampling, season of sampling, time of sampling, and IP or OP farm.

Data Analyses

General aspects. Data were recorded and stored in Excel spreadsheets and merged within an Access database. Initial descriptive data analyses were performed using NCSS 2001 (www.ncss.com). Interval and score data are presented as median and 2.5th to 97.5th percentile ranges (**range_p**). For ordinal and nominal variables, counts and percentages were used. For the majority of the analyses, results from visit 2 (target: 30 d postpartum) were used.

Comparison between OP and IP farms. For variables measured at the farm level, a matched analysis (with the 60 farm pairs as matching or repetition variable) was used. Association between farm type (OP and IP) and categorical (binary, nominal, and ordinal) variables were assessed in a univariable matched logistic regression routine (clogit) in Intercooled STATA v.7 (Stata Corp., College Station, TX). All continuously (interval) measured variables were first ranked by ascending value, and a repeated-measures ANOVA on these ranked values with farm type as factor A and the matching (farm pairs) as repetition factor was performed.

It was impossible to correct for both matching and clustering of cows within farms in 1 analysis. Therefore, association between farm type (OP and IP) and categorical cow-level variables was assessed using an univariable logistic regression model with correction for farm-level clustering [STATA logistic, `r cl(farm)`]. All cow-level interval data such as ECM yield (kg/cow per d) were categorized into 4 levels based on quartiles and subsequently analyzed as categorical variables. Thus, in this approach, the proportion of OP cows (relative to IP cows) in each quartile category was compared. For example, a large proportion of OP cows in the lowest quartile category of ECM and a small proportion in the highest ECM quartile indicated more ECM yield in IP than OP cows.

Identification of risk factors for poor milk yield (binary outcome). Farms were not matched for this outcome (milk yield), but clustering of cows within farms was still present. After classifying cows as poor or good milk producers, association between yield status and categorical farm as well as cow-level variables was assessed using an univariable logistic regression model with correction for farm-level clustering [STATA logistic, `r cl(farm)`]. Again, all interval data were categorized into 4 levels based on quartiles and subsequently analyzed as categorical (ordinal) variables because a

true linear relationship in the odds ratios (OR) could not be assumed. Results were expressed as OR, which indicated the probability that cows in the respective risk factor level would have a poor milk yield compared with cows in the baseline risk factor level. Variables that resulted in an univariable *P* value < 0.10 in at least one of their levels were selected as potential candidates for the multivariable model approach. This candidate list was screened, and of those variables that explained the same biological phenomenon, the respective variable with the strongest univariate association to poor milk yield (lowest *P* value) was retained to avoid multicollinearity problems in the final model. In addition, variables with fewer than 20 observations (cows) in one of the outcome categories were excluded from further analysis to avoid model conversion and estimation problems. Finally, a correlation analysis of all remaining candidate variables was done, and variable pairs with a correlation coefficient > 0.75 were identified. From each of those variable pairs, 1 variable was omitted to avoid collinearity.

The selected potential risk factors were analyzed in a stepwise logistic regression model with hierarchical forward selection and hierarchical backward elimination, both with swapping (reassessment of previously included or excluded variables). The *P* values for data inclusion and exclusion were set at 0.05 and 0.051, respectively. Farm identity was again included as a cluster variable. Odds ratios and 95% confidence intervals of variables associated with poor milk yield were estimated in a final logistic regression that contained all variables that had entered or were retained in the stepwise procedures. Also in that model were farm identity as a cluster variable, farm type (OP or IP), agricultural zone (3 categories depending on altitude above sea level), and number of adult cows on the farm (as an ordinal variable based on quartiles). The latter 3 variables were forced into the final model as study design variables (matching factors between OP and IP farms) to adjust for their potential confounding effect. No additional confounders or 2-way and higher-level interaction terms were considered in this analysis.

To assess the association between interval and ordinal variables, Spearman's rank correlation coefficients (*r_{sp}*) were calculated.

The level of statistical significance for all comparisons, when not otherwise indicated, was set to 0.05.

RESULTS

General Data

On average, the OP farms in the study had been certified for 6 yr (**range_p** 4 to 24 yr). The farm visits took place at a median of 29 d prepartum (**range_p** 55 d

Table 1. Concentrates fed to dairy cows on 60 organic milk-producing (OP) farms and 60 farms with integrated (conventional) production (IP) at 31 and 102 d (medians) of lactation.¹

	Visit 2 ²		Visit 3 ³		OP vs. IP (visit 2)		OR
	OP cows (n = 483)	IP cows (n = 487)	OP cows (n = 419)	IP cows (n = 421)	Amount quartile	OP cows, %	
Concentrate feeding							
Cows receiving concentrates, %	87	91	81	88	1	61	Baseline
Concentrates fed, kg/cow per d	2	3	2	2	2	56	0.81
					3	45	0.53
					4	41	0.44 ⁴
Percentile range	0–7	0–7	0–6	0–5.5			

¹Data are presented as medians and 2.5th to 97.5th percentile ranges. The proportion of cows in the 4 concentrate quartiles was compared between OP and IP cows during visit 2 by using odds ratios (OR) from a univariable logistic regression analysis.

²Median of 31 d postpartum.

³Median of 102 d postpartum.

⁴Differs ($P < 0.05$) from quartile 1 for percentage of OP cows.

prepartum to 5 d postpartum; visit 1), 31 d postpartum (range_p 21 to 42 d; visit 2), and 102 d postpartum (range_p 85 to 124 d; visit 3).

In total, 483 OP cows and 487 IP cows were available during visits 1 and 2, and of those, 419 OP and 421 IP cows were still available during visit 3. Breed composition on OP farms was 55.1% Simmental × Red Holstein crossbreed, 19.7% Red and Black Holstein, 18.8% Simmental, and 6.4% Brown Swiss, Jersey, and Montbéliard. Breed composition on IP farms was 49.1% Simmental × Red Holstein, 26.1% Red and Black Holstein, 19.3% Simmental, and 5.5% Brown Swiss, Jersey, and Montbéliard. Median cow age during visit 2 was 5.3 yr (3.2 to 10.9 yr) for OP cows and 5.2 yr (3.1 to 11 yr) for IP cows. Differences in breed composition and cow age were not significant among farm types.

Feeding

Individual cow feeding based on feeding plans on OP and IP farms was similar. The number of farms that fed roughage containing predominantly legumes and beets and of farms that fed rapeseed or soy extraction meals during winter was greater ($P < 0.05$) on IP than OP farms. There was a trend for more brewers' grains and malt to be fed to cows on OP than IP farms.

During visit 2, 87% of the OP cows, and 91% of IP cows received concentrates. This changed to 81 and 88% by visit 3 (median 102 d postpartum). The proportion of cows that received greater amounts of concentrates was smaller ($P < 0.05$) on OP than IP farms (quartile analysis, OR = 0.44; Table 1). Only 11% of OP farms and 26% of IP farms used protein supplements in their feed during visit 2. These percentages changed to 8 and 21% by visit 3 (median: 102 d postpartum). Differences in percentages between OP and IP farms differed ($P < 0.05$). Median amounts of fed protein supplements were

1 kg/d and cow on IP farms, and 0.5 kg/d and cow on OP farms.

Milk Production and Milk Composition

The ECM yield during visit 2 was 25.7 (16.1 to 37.6) kg/d for OP cows and 28.5 (17.6 to 42.1) kg/d for IP cows. The proportion (%) of OP cows (compared with IP cows) in the 4 ECM yield quartiles decreased ($P < 0.05$) with increasing ECM quartile during visits 2 and 3 (Table 2 and Figure 1). Concentrations of milk fat, protein, and lactose, and lactation persistency differed ($P < 0.05$) between OP and IP farms, but the differences in quartile proportions were not significant. Proportions (%) of OP cows (compared with IP cows) in the 4 blood urea quartiles were less ($P < 0.05$) for higher blood urea quartiles during visits 2 and 3 (Table 2).

Median ECM yields were less ($P < 0.05$) in OP than IP cows for all lactation numbers (Figure 2). Medians of ECM yields of OP cows reached maximal daily milk yields at the sixth lactation, whereas IP cows reached maximal yields at the third lactation. Yields declined after the sixth lactation in OP cows, whereas IP cows maintained relatively high yields up to the seventh lactation. Median daily ECM yields were less in OP than IP cows during spring (26.1 and 29.2 kg, respectively, $P < 0.001$), summer (24.4 and 26.7 kg, respectively), winter (25.6 and 29.1 kg, respectively; $P < 0.001$), and fall (27.1 and 29.1 kg, respectively; $P < 0.05$).

Udder suspension was good, mediocre, and poor in 342, 96, and 22 OP cows and in 336, 104, and 25 IP cows, respectively. No differences were detected between farm types for cows with good vs. mediocre/poor udder suspension.

Table 2. Energy-corrected milk yield (ECM), milk composition, and lactation persistency of dairy cows on 60 organic milk-producing farms (OP) and 60 farms with integrated (conventional) production (IP).¹

Trait	Visit 2 ²						Visit 3 ³					
	OP cows			IP cows			OP cows			IP cows		
	No.			No.		% OP cows in quartile (Q)	No.			No.		% OP cows in quartile (Q)
ECM, kg/d	476	25.7 16.1–37.6 Q1 = 61.9%		480	28.5 17.6–42.1	Q2 = 56.8 Q3 = 44.8 ⁴ Q4 = 35.1 ⁴	413	21.6 13.1–32.7 Q1 = 59.8%		416	24.7 15.2–38.0	Q2 = 49.7 Q3 = 34.2 ⁴ Q4 = 24.0 ⁴
Milk fat, g/kg	474	38.4 26.9–50.1 Q1 = 52.3%		480	38.7 28.7–51.3	Q2 = 48.5 Q3 = 49.2 Q4 = 48.7	413	37.3 27.5–50.9 Q1 = 54.5%		416	37.8 29.1–50.8	Q2 = 46.9 Q3 = 47.6 Q4 = 50.3
Milk protein, g/kg	474	30.0 25.2–38.6 Q1 = 52.5%		480	30.3 25.2–38.0	Q2 = 50.2 Q3 = 49.5 Q4 = 45.2	413	30.7 26.2–36.1 Q1 = 56.7%		416	31.2 26.2–36.8	Q2 = 53.0 Q3 = 48.7 Q4 = 43.3
Milk urea, g/kg	474	20.0 7.0–41.0 Q1 = 57.0%		480	22.0 8.0–42.0	Q2 = 51.5 Q3 = 43.5 ⁴ Q4 = 45.9	413	18.0 5.4–37.7 Q1 = 59.1%		416	21.0 9.0–39.0	Q2 = 46.0 ⁴ Q3 = 43.1 ⁴ Q4 = 47.1
Milk lactose, g/kg	474	4.9 4.6–5.2 Q1 = 52.0%		480	4.9 4.6–5.2	Q2 = 50.4 Q3 = 49.4 Q4 = 46.6	413	4.9 4.5–5.2 Q1 = 52.0%		416	4.9 4.5–5.2	Q2 = 52.6 Q3 = 44.3 Q4 = 47.5
Persistency, % change in kg of ECM	112	103 76–131 Q1 = 44.3%		122	101 80–127	Q2 = 43.1 Q3 = 46.7 Q4 = 58.2	413	92 71–117 Q1 = 49.0%		416	92 71–117	Q2 = 52.8 Q3 = 46.9 Q4 = 51.2

¹Data are presented as medians, 2.5th to 97.5th percentile ranges, and percentage of OP cows in lowest quartile (Q) category (baseline). The percentages of cows in quartile-based categories were compared between OP and IP farms by univariable logistic regression.

²Median of 31 d postpartum.

³Median of 102 d postpartum.

⁴Differs ($P < 0.05$) from quartile 1 for percentage of OP cows.

Figure 1. Proportion of OP cows (together with IP cows: 100%) in each energy-corrected milk yield (ECM, kg/d) quartile. Study included 970 Swiss dairy cows on 60 organic milk-producing farms (OP) and 60 farms with integrated (conventional) production (IP). Measurements were assessed at 2 visits during lactation. Visit 2 (median 31 d postpartum) = black bars; visit 3 = (median 102 d postpartum) white bars.

Figure 2. Energy-corrected milk yield (ECM, kg/d) of 970 Swiss dairy cows on 60 organic milk-producing farms (OP) and 60 farms with integrated (conventional) production farms (IP) at different ages (lactation numbers), measured at a median of 31 d postpartum. Numbers below the abscissa represent the frequency of cows by farm type and lactation.

Blood Plasma Metabolite and Hormone Concentrations

During visit 2, a greater proportion of plasma albumin, urea, and IGF-I concentrations in OP cows was in the lower quartile categories, whereas respective concentrations of IP cows were in the higher quartile categories. These proportions differed ($P < 0.05$) for plasma albumin and urea, in contrast to those for plasma glucose, NEFA, BHBA, and T_3 concentrations; therefore, quartile percentages of OP and IP cows did not differ (Table 3). Plasma urea concentrations were similar in OP and IP cows during summer, but concentrations were less ($P < 0.001$) in OP than IP cows during winter (3.2 and 3.8 mmol/L, respectively). Urea concentrations in plasma and milk were positively correlated ($r_{sp} = 0.48$; $P < 0.001$), but not between plasma albumin with milk protein concentrations. No significant differences were detected for concentrations of measured traits collected at different times of the day (data not shown).

BCS and BW

Median BCS did not differ between OP and IP cows during any of the 3 visits (Table 4). However, at visit 1, only 21% of all OP cows were in the BCS quartile 1 (lowest BCS range), whereas the percentages were greater ($P < 0.05$) in BCS quartiles 2 to 4 (57.8, 57.9, and 47.2%, respectively; Table 4). Extreme BCS values

were detected in 32 cows: 15 OP and 12 IP had BCS > 4 during visit 1, whereas 4 IP and 1 OP had BCS < 2 during visit 3. More ($P < 0.05$) OP cows had a larger BCS change (decrease) between visits 1 and 2 compared with IP cows. The proportion of OP and IP cows in the different BCS quartile categories did not differ from baseline (Q1) during visits 2 and 3.

The BW was always less ($P < 0.05$) in OP than IP cows (Table 4). However, BW losses from the first to the second visit and from the second to the third visit did not differ between OP and IP cows. Weak positive correlations were detected between BCS and BW (visit 1: $r_{sp} = 0.38$, $P < 0.0001$; visit 2: $r_{sp} = 0.27$, $P < 0.0001$; visit 3: $r_{sp} = 0.22$, $P < 0.0001$).

Reproductive Performance

During the actual study, 30.8 and 29.4% of OP and IP cows calved during the summer feeding period, and 69.2 and 70.6% of OP and IP cows calved during the winter feeding period. Days to first service in OP and IP cows did not differ (medians 65 and 68 d, respectively), but showed large variability (2.5th to 97.5th percentiles: 33 to 146 d and 28 to 133 d for OP and IP cows, respectively). Although the percentage of OP cows (compared with IP cows) decreased from 56.3% in the lowest quartile (shortest waiting period) to 45.1% in the highest quartile (longest waiting period), no difference

Table 3. Blood plasma metabolite and hormone concentrations of dairy cows on 60 organic milk-producing farms (OP) and 60 farms with integrated (conventional) production (IP).¹

Trait	OP cows		IP cows		% OP cows in quartile (Q)
	No.		No.		
Glucose, mmol/L	483	3.36 2.24–4.13 Q1 = 49.2%	487	3.41 2.30–4.30	Q2 = 51.8 Q3 = 46.6 Q4 = 51.5
NEFA, μ mol/L	483	155 52–532 Q1 = 49.2%	159	47–592	Q2 = 51.9 Q3 = 48.1 Q4 = 50.0
BHBA, mmol/L	483	0.9 0.45–3.41 Q1 = 49.8%	487	0.9 0.43–3.67	Q2 = 49.8 Q3 = 51.7 Q4 = 48.0
Albumin, g/L	486	39.5 34.5–44.0 Q1 = 59.5%	487	40.3 35.3–45.0	Q2 = 53.6 Q3 = 48.0 ² Q4 = 38.3 ²
Urea, mmol/L	783	3.7 1.43–7.57 Q1 = 60.3%	487	4.0 1.48–7.59	Q2 = 49.4 Q3 = 47.9 Q4 = 41.6 ²
Insulin-like growth factor-1, μ g/L	482	71 30–153 Q1 = 55.0%	487	78 26–151	Q2 = 54.3 Q3 = 43.8 Q4 = 45.9
3, 5, 3'-Triiodothyronine, nmol/L	483	1.2 0.38–2.50 Q1 = 48.0%		1.2 0.43–2.29	Q2 = 49.2 Q3 = 51.9 Q4 = 50.2

¹Blood samples were collected at 31 d postpartum (median). Data are presented as medians, 2.5th to 97.5th percentile ranges, and as percentage of OP cows in lowest quartile (Q) category (baseline). The proportion of cows in amount categories (based on quartiles) was compared between OP and IP farms by univariable logistic regression.

²Differs ($P < 0.05$) from quartile 1 (baseline) for percentage of OP cows.

was detected ($P = 0.07$). For the calving interval, 55 and 54% of OP cows (compared with IP cows) were in quartiles 1 and 4, and 46 and 45% were in quartiles 2 and 3, respectively, but differences were not significant.

Analysis of Factors Associated with Poor Milk Production

Low-yielding cows were defined as those with an ECM (up to 305 d) of <5808 kg in the preceding lactation, whereas cows having ≥ 5808 kg of ECM were classified as high-yielding cows. Of approximately 150 variables tested for their univariable association with poor milk yield, 23 (including ECM of the current and of the previous lactation) had P values < 0.05. An additional 13 variables had P values between 0.05 and 0.10 (the cutoff for inclusion as candidates in the multivariable model). After exclusion of ECM (as being transformations that were highly correlated with the binary outcome) and 2 additional variables out of highly correlated ($r > 0.75$) variable pairs, 43 variables were offered to the forward and backward selection procedure of the multivariable logistic regression. In the forward selection, 16 of the 43 variables were added to the model.

All but one of those and an additional 5 variables were retained in the backward elimination process (models not shown). In the final model, OR estimates for milk yield were calculated for 13 variables describing cow-dependent traits (Table 5), 7 variables describing farm-level traits, and the 3 design variables farm type, elevation zone, and number of adult cows on the farm (Table 6).

Based on the 95% confidence intervals for the OR estimates, BCS change between visits 1 and 2, assessment of first milk, hoof trimming, presence of a cow trainer, length of bedding, as well as the design variables of farm type (OP vs. IP) and number of adult cows on the farm were no longer significant risk factors for low milk yield (Tables 5 and 6).

The odds for low milk yield were increased ($P < 0.05$) for purebred Simmental cows and decreased ($P < 0.05$) for purebred Holstein cows. In comparison to the odds (chance) of low milk yield (vs. high yield) in the lowest respective quartile range, the odds for low milk yield decreased ($P < 0.05$) with increasing (quartiles of) BW, lactation number, blood albumin levels, milk fat, and milk protein levels during the previous lactation, persistency during the previous lactation, and calving in-

Table 4. Body condition scores and BW of dairy cows on 60 organic milk-producing farms (OP) and 60 farms with integrated (conventional) production (IP).¹

Trait	OP cows		IP cows		% OP cows in quartile (Q)
	No.		No.		
BCS at visit 1 ²	483	3.25 2.75–4.23 Q1 = 21.1%	487	3.25 2.5–4.25	Q2 = 57.8 ² Q3 = 57.9 ² Q4 = 47.2 ²
BCS at visit 2 ³	483	3.0 2.25–3.75 Q1 = 49.8%	487	3.0 2.25–3.75	Q2 = 53.9 Q3 = 46.2 Q4 = 49.6
BCS at visit 3 ⁴	419	2.75 2.0–3.5 Q1 = 50.5%	421	2.75 2.0–3.6	Q2 = 49.0 Q3 = 53.1 Q4 = 45.6
BW (kg) at visit 1 ³	483	680 550–842 Q1 = 60.8%	487	710 540–871	Q2 = 54.0 Q3 = 55.8 Q4 = 41.8 ²
BW (kg) at visit 2 ⁴	483	640 510–778 Q1 = 59.4%	487	658 510–811	Q2 = 51.0 Q3 = 47.9 ² Q4 = 38.7 ²
BW (kg) at visit 3 ⁵	419	630 502–750 Q1 = 59.4%	421	650 507–800	Q2 = 54.2 Q3 = 44.8 ² Q4 = 33.6 ²

¹Data are presented as medians, 2.5th to 97.5th percentile ranges, and percentage of OP cows in lowest quartile (Q) category (baseline). Frequency of cows in BCS quartile categories were compared between OP and IP farms by univariable logistic regression.

²Differs ($P < 0.05$) from quartile 1 (baseline) for percentage of OP cows.

³Median of 31 d postpartum.

⁴Median of 102 d postpartum.

⁵Median of 31 d postpartum.

Table 5. Cow-level risk factors for low milk in a multivariable logistic regression model for dairy cows on 60 organic milk-producing farms (OP) and 60 dairy farms with integrated (conventional) production (IP).¹

Variable	Risk factor for low milk yield ¹						
	L1 baseline	L2 coding and OR	L3 coding and OR	L4 coding and OR			
Breed ²	Si × RH	Si	3.15 (1.68–5.91)	Ho	0.33 (0.19–0.58)	Other	0.63 (0.26–1.54)
Cow weight, kg	Q1 ³	Q2	0.44 (0.27–0.74)	Q3	0.33 (0.19–0.59)	Q4	0.23 (0.12–0.46)
BCS	Q1	Q2	1.84 (1.02–3.30)	Q3	2.12 (1.15–3.93)	Q4	3.01 (1.48–6.10)
Lactation number	Q1	Q2	0.16 (0.09–0.29)	Q3	0.07 (0.04–0.13)	Q4	0.04 (0.02–0.09)
Udder suspension ⁴	Good	M/P	0.56 (0.34–0.91)	...	...	...	...
BCS change (29 d prepartum to 31 d postpartum)	Q1	Q2	1.33 (0.77–2.29)	Q3	0.83 (0.48–1.44)	Q4	1.86 (0.83–4.13)
Blood albumin, g/L	Q1	Q2	0.79 (0.46–1.36)	Q3	0.44 (0.25–0.76)	Q4	0.68 (0.39–1.19)
Milk fat, % in previous lactation	Q1	Q2	0.55 (0.32–0.94)	Q3	0.56 (0.32–0.98)	Q4	0.47 (0.26–0.85)
Milk protein, % in previous lactation	Q1	Q2	0.87 (0.51–1.49)	Q3	0.43 (0.24–0.77)	Q4	0.76 (0.41–1.39)
Persistency, % in previous lactation	Q1	Q2	0.57 (0.34–0.97)	Q3	0.54 (0.30–0.95)	Q4	0.39 (0.22–0.71)
California mastitis test 1+ positive in either hind quarter	No	Yes	1.83 (1.17–2.86)				
Concentrates fed, kg/cow per d	Q1	Q2	1.45 (0.81–2.59)	Q3	1.46 (0.77–2.75)	Q4	0.38 (0.21–0.67)
Calving interval, d	Q1	Q2	0.42 (0.25–0.71)	Q3	0.29 (0.17–0.51)	Q4	0.20 (0.12–0.36)
Season at sampling	Winter ⁵	S	1.67 (1.06–2.65)	...	...	...	...

¹Results are presented as odds ratios (OR) and confidence intervals (CI) for low milk yield (below median of study population) compared with cows with high milk yield. Number of adult cows per farm, farm type and elevation zone were entered as design variables into the final linear regression model. The abbreviations L1 to L4 represent the up to 4 levels of the categorical or ordinal variables in the model.

²Si × RH = Simmental × Holstein; Si = Simmental; Ho = Red and Black Holstein; other = breed other than Si × RH, Si and Ho (combined).

³Q = Quartile.

⁴Good vs. mediocre/poor (combined).

⁵October to March.

Table 6. Farm-level risk factors and design variables/confounders in a multivariable logistic regression model for dairy cows with low milk yield on 60 organic milk-producing farms (OP) and 60 farms with integrated production (IP).¹

Variables	Risk factor for low milk yield					
	L1 baseline	L2 coding and OR	L3 coding and OR	L4 coding and OR		
Routine teat dipping	No	Yes	0.40 (0.26–0.64)	...	...	...
Assessment of first milk	No	Yes	0.72 (0.46–1.12)	...	...	...
Winter outdoor access (h/d)	<1	Q2 ²	0.42 (0.25–0.69)	Q3	0.35 (0.21–0.60)	...
Hoof trimming	Once a year	>1	0.75 (0.47–1.18)	...	...	...
Cow trainer	No	Yes	0.64 (0.39–1.07)	...	...	...
Length of bedding (cm)	Q1	Q2	0.60 (0.31–1.14)	Q3	0.80 (0.47–1.37)	Q4 0.56 (0.30–1.03)
Farm type	IP	Q2	1.25 (0.76–2.04)	...	...	...
Elevation zone (m above sea level)	Zone 1	Z2	2.16 (1.26–3.68)	Z3	1.18 (0.56–2.52)	...
No. of adult cows on farm	Q1	Q2	0.95 (0.51–1.74)	Q3	1.11 (0.60–2.06)	Q4 0.63 (0.34–1.19)

¹Results are presented as odds ratios (OR) and confidence intervals (CI) for low milk yield (below median of study population) compared with cows with high milk yield. Number of adult cows per farm, farm type, and elevation zone were entered as design variables into the final logistic regression model. The abbreviations L1 to L4 represent the up to 4 levels of the categorical or ordinal variables in the model.

²Q = quartile.

terval. Significant reduction in low-yield odds was also detected for cows or farms having routine teat dipping (OR = 0.4), increased access to exercise lots during winter (OR = 0.42 and 0.35), and mediocre/poor udder suspension (vs. good udder suspension, OR = 0.56), and for cows receiving the largest amount of concentrates (OR = 0.38). The low-yield odds were increased for cows that had CMT = 1+ or greater on 1 or both hindquarters (OR = 1.83), and for sampling during the summer season (OR = 1.67). An increase ($P < 0.05$) in low yield odds (1.84, 2.12, and 3.01) was detected with increasing BCS quartile (Tables 5 and 6).

DISCUSSION

General Aspects

This study was the first in Switzerland to compare feeding, reproductive performance, and milk production among dairy cows on OP and IP dairy farms. The study included only farms that were members of a breeder organization, and for practical reasons, were limited to farms located in the canton of Bern. This limitation possibly resulted in some selection bias because only 72% of Swiss OP and IP dairy cows during the time of the study were registered in a herd book, (genetics of each cow was known; Schweizerischer Bauernverband; personal communication, 2003). Average size of selected farms, however, was close to the Swiss national average; and based on the selection procedure, the farms in the study were sufficiently representative to allow extrapolation of the results to the general Swiss herd book registered dairy farm and dairy cow population.

The analysis was mainly complicated by matching of geographic location, similar altitude, herd size, and by the hierarchical data structure with observation from

multiple cows per farm. For those variables measured at the farm level, matching was accounted for during the comparison between farm types (OP vs. IP). These variables were also analyzed in parallel using an unmatched logistic regression approach. The same risk factors were identified as significant when OR estimates were in the same direction and numerically only slightly different (results not shown). Based on that general agreement of analyses, we are confident that variables measured at the cow level ignore the effect of matching, but account for the clustering effect when deriving the OR estimates.

Feeding, Milk Production, BCS, BW, Blood Traits, and Fertility

Number of farms feeding roughages containing predominantly legumes, beets, and rapeseed or soybean meal (during winter) as well as number of cows and amounts of concentrates fed was greater in IP than OP farms and was in accordance with other European (Krutzinna et al. 1996; Byström et al., 2002; Thuen et al., 2002) and Swiss studies (Augstburger et al., 1988; Trachsel et al., 2000). Compared with conventional milk production in other European countries (Byström et al. 2002) and in high-yielding dairy cows in Switzerland (Aeberhard et al., 2001b), use of concentrates on IP farms was low. However, farm management traits such as the start of concentrate feeding prepartum, separate feeding of dry cows, allocation of concentrates according to performance, use of automatic feeding, feed mixers, and TMR was similar in OP and IP cows (Roesch, 2004).

Milk production was less in OP than in IP cows, which was in accordance with other studies (Krutzinna et al., 1996; Byström et al., 2002; Hamilton et al., 2002). Lactation persistency, however, was not different in OP

and IP cows. Interestingly, OP cows reached maximal daily milk yields during their sixth lactation, whereas IP cows already reached maximal yields during their third lactation. The age-dependent pattern of milk yields possibly reflected better genetics and (or) nutrition in IP than OP cows.

Median values of milk fat, lactose, protein, and urea concentrations were within the normal range and comparable with findings reported by Braun et al. (1983) for Brown Swiss cows. Protein, fat, and urea concentrations varied among farm visits, whereas lactose concentration was constant. This was not surprising because milk protein, urea, and fat during early lactation are indicators of energy balance, whereas lactose concentration usually does not change during energy deficiency (Braun et al., 1983), although exceptions exist (Reist et al., 2002, 2003a). Milk urea and protein percentages were less in OP than IP cows during visits 2 and 3. Amounts of concentrates and protein supplements fed to OP cows were less than that fed to IP cows, which, in part, explains the slightly lower milk protein and urea concentrations in OP than IP cows. Less protein or urea concentrations in OP than in conventional herds were also found in other studies (Krutzinna et al., 1996; Busato et al., 2000; Byström et al., 2002).

Blood samples were measured during visit 2 (i.e., when cows were metabolically most challenged. Although it is known that some of the measured blood metabolites can change during a 24-h period and vary according to when feeding occurred (Blum et al., 1985, 2000; Clément et al., 1988), effects due to different bleeding times were not found in the present study. Measured blood measures served as monitors of changes in intake and metabolism of energy (Kunz et al., 1985; Ronge et al., 1988; Reist et al., 2002, 2003a,b) and protein (Clément et al., 1991). Based on these experimental studies, and in additional field studies (Aeberhard et al., 2001a; Busato et al., 2002), concentrations of the various blood measures were in the normal range, suggesting that energy and nutrient intakes were not abnormal in either OP or IP cows. Their ketone status agreed with that of other studies (Hamilton et al., 2002; Reist et al., 2003b). No significant differences between OP and IP cows were detected, except for plasma albumin, urea, and IGF-I concentrations. Lower plasma albumin and urea concentrations in OP than IP cows agreed with lower protein and urea concentrations in milk and supported previous observations that indicated a relatively small CP intake in OP cows during winter (Trachsel et al., 2000) and were consistent with less protein and energy intake under experimental conditions (Ronge et al., 1988; Clément et al., 1991). The slightly lower plasma concentrations of IGF-I in

OP than IP cows, too, indicated slightly lower energy and protein intake in OP than IP cows (Ronge et al., 1988; Reist et al., 2003a).

The absolute BCS and changes in BCS served as indirect indicators of energy balance (Busato et al., 2002; Reist et al., 2002). The BCS median scores did not differ between OP and IP farms during any of the 3 farm visits, which supports the conclusion derived from blood and milk analyses that energy intakes in OP and IP cows were similar. A small number of cows (about 3%) of both groups had extreme BCS (<2 or >4) during visits 1, 2, and 3, but numbers of cows having worse or better BCS did not differ between OP and IP cows. These results seemed to differ from those reported in a previous study in Swiss OP farms (Trachsel et al., 2000), in which 7% of cows had a BCS < 2 or > 4, respectively. The quartile analysis of BCS in the present study, however, indicated that more OP than IP cows had higher BCS during visit 1, which is consistent with the study of Trachsel et al. (2000) in which BCS frequency distribution indicated that a relatively large number of OP cows had elevated BCS. In contrast, the decrease in BCS between visits 1 and 2 was more pronounced in OP than IP cows, indicating greater fat mobilization in OP than IP cows, possibly due to insufficient energy intake.

Average BW of OP cows was less than that of IP cows, consistent with observations of Byström et al. (2002). However, BW reductions during the dry period and during lactation of OP and IP cows were similar. Lower BW might have been due to less body fat content, based on carcass composition of OP cows (Hansson et al., 2000) or due to different breeding strategies. Thus, Aeberhard et al. (2001b) found that high-yielding cows differed from lower yielding cows within the same herd in body conformation traits. Greater BW of IP than OP cows may have been the result of more purebred Holstein cows in IP herds, as suggested by Byström et al. (2002). In the present study, a tendency existed for more purebred Holstein cows and for more crossbred Red Holstein-Simmental to be found in IP than OP farms.

Fertility was generally good and did not differ between OP and IP farms. This is supported by findings of other studies in Switzerland, Germany, Norway, Sweden, and Denmark (Augstburger et al., 1988; Krutzinna et al., 1996; Reksen et al., 1999; Byström et al., 2002; Hamilton et al., 2002).

Analysis of Factors Associated with Low Milk Yields

As expected, breed had a strong impact on milk yield. Simmental cows had the lowest milk yields, whereas

purebred Holsteins and cows of other breeds (Jersey, Montbéliard, and Brown Swiss breeds) were associated with relatively high milk yields.

Increasing lactation number was negatively associated with poor milk yields. Yields of cows increased in the present study up to 5 to 8 yr. Because the median age of OP and IP cows in our study was 5.3 and 5.2 yr, respectively, the majority of cows in our study had not yet reached their maximum yields. The OP cows reached maximal yields during their sixth lactation (i.e., at 6 to 9 yr of age and later than IP cows). Studies from other countries report longer productive life of OP cows with increasing years after conversion from conventional to organic farming (Lund and Algers, 2003). The OP farmers seem to have different strategies than IP farmers with respect to lactation performance and cow replacement.

Concentrate and protein supplementation were negatively associated with poor milk yields, but this only differed in this study for the highest quartile of amounts of concentrates fed. The effect was more pronounced in IP cows (analysis not shown), in which amounts of protein supplements fed were greater than in OP cows. Lower milk yield in OP than IP cows was in part due to restricted feeding of concentrates.

The negative association between increasing plasma albumin concentrations and poor milk yields was likely due to differences in protein intake, and agrees with the finding that plasma albumin concentrations were less in OP than IP cows. Although plasma albumin does not directly contribute to the formation of milk proteins, it serves as an indicator of the nutritional protein status.

Increasing BCS quartile categories, when compared with the baseline BCS quartile (median BCS = 2.5) resulted in an increased OR for poor milk yield. Greater changes in BCS from 29 d prepartum to 31 d postpartum were least in the largest BCS change quartile and were weakly associated with smaller milk yields. In our study, cows having less prepartum BCS and small to moderate loss in BCS had increased odds for more milk yield. Enhanced fat and some protein mobilization, which may result in large BCS losses, were shown to be typical for greater milk yields (Bines, 1976; Hart et al., 1978). However, marked differences in BCS losses under practical conditions are only partly associated with milk yield (Aeberhard et al., 2001b; Busato et al., 2002).

Smaller BW during lactation was positively associated with poor milk yields (i.e., milk yields increased with increasing BW). It has been shown that high-yielding Swiss dairy cows are larger than poorer yielding cows (Aeberhard et al., 2001b). High-yielding cows generally tend to become larger when they produce more

milk, although small cows are energetically more efficient (Hoffman and Funk, 1992).

Only large udders have sufficient synthetic capacity and space to store large amounts of synthesized and secreted milk (Johansson et al., 1966). In our study, mediocre to poor udder suspension was associated with more milk yield, whereas good udder suspension was positively associated with less milk yield. The number of cows in our study having poorly suspended udders was too small, however, to differentiate between mediocre and poor suspension. In other studies, poorly suspended udders were most often seen in older cows, and this was usually associated with milking difficulties, especially longer times needed to milk hindquarters (Johansson et al., 1966). Traumatization or infections of hindquarters can be the consequence (Johansson et al., 1966). The proportion of OP and IP cows within different udder suspension categories did not differ.

Milk fat concentration during the previous lactation was negatively associated with poor milk yields. Milk fat concentration depends on many factors such as genetics, stage of lactation, and nutrition. Holstein cows had elevated milk fat percentages in our study, which may partly explain the negative association of the milk fat content with poor yields. Because all cows were evaluated at similar stages of lactation, differences in stages can largely be excluded. As far as nutrition is concerned, obvious differences existed with respect to energy and protein intakes between OP and IP cows. However, no differences in milk fat content were detected between OP and IP cows. Although insufficient energy intake is followed by enhanced fat mobilization and incorporation of long-chain fatty acids into milk and contributes to increased milk fat content, this was unlikely because measures of fat mobilization (such as plasma NEFA) did not differ between OP and IP cows. The observed decrease in BCS across parturition was more pronounced in OP than IP cows, which could have contributed to high fat contents and the association with poor milk yield.

Mastitis (positive CMT and high SCC) is known to be associated with decreased milk yield. A previous study showed that the frequency of subclinical mastitis in Swiss OP farms is elevated and likely responsible for relatively poor milk yields (Busato et al., 2000). In the present study, the number of quarters having a positive CMT at 21 to 43 d postpartum was greater in OP than in IP cows, and the SCC on test days were greater in OP than IP cows (Roesch, 2004). In agreement with our results, a positive association was detected between cows having a positive CMT in both hindquarters and poor milk yields. This positive association was in contrast to previous findings (Busato et al., 2000), and may indicate that farms that performed

CMT regularly did this because they had problems with udder hygiene and increased herd SCC (and already reduced yields). On the other hand, routine teat dipping done after milking decreased the risk for poor milk yield. This association could be indirect, that is, it may express an increased hygiene management approach that results in more milk yield. In contrast, a direct association may exist wherein teat dipping decreases the probability of udder infections and subsequently less yield. In our study, none of the SCC measures that were borderline significant in the univariable analysis entered the final risk factor model for poor milk yield.

Incidence of milk fever (postparturient hypocalcemia) in the present study was not different between OP and IP cows, but cows having milk fever had poorer yields during the lactation under study. On the other hand, increased occurrence of milk fever was positively associated with more milk production in the preceding lactation, and milk fever was positively associated with large milk yields, especially in OP cows (Roesch, 2004).

Access to an outdoor paddock during winter for more than 1 h/d was negatively associated with poor milk yield compared with spending 1 h/d or less outside. Reasons for this finding are unclear, but it cannot be fully excluded that more exercise might have improved well being of cows that spent more time outside than others.

Cows exposed to a cow trainer had reduced odds of poor milk yield. Although exceptions exist (Valde et al., 1997), it is generally held that incidence of mastitis is higher in free stall barns than in barns where cows are tied up, especially if straw bedding in free stall barns is poor and dirty. Schreiner and Ruegg (2003) found a positive association between leg hygiene scores and the prevalence of intramammary udder pathogens. It is also known that bedding in barns is cleaner with a cow trainer, thus reducing the chance of udder infections. Tied-up cows exposed to a cow trainer might have greater milk yields because they experience less mastitis.

When summarizing the results of the multivariable logistic regression model for poor milk yield, several factors that in combination might describe a specific farm management profile (breed selection, high concentrate feeding, routine teat dipping, and assessment of first milk, more access to outside exercise lots during winter, regular hoof trimming, presence of a cow trainer, and length of the stalls) were associated with less milk yield in OP than IP cows. It is likely that it is not only their individual association, but also the overall farm management profile that is responsible for the categorization into low- and high-yielding cows. The identified individual factors stand as indicator variables for that production system.

In conclusion, ECM yields were less in OP than IP cows. Fertility was generally good and no differences were detected between OP and IP cows. Factors having an impact on poor milk yield were breed, age, BW, BCS, plasma albumin concentration, udder suspension, and fat content of milk during the preceding lactation. Various management factors were associated with poor milk yield such as amounts of concentrates and protein fed and teat dipping. To avoid reduced milk yield, OP farmers should ensure good udder health is maintained despite restrictions in the use of antibiotics, feed (especially energy and proteins) according to requirements of the cows, and maintain more older cows in their herd. Although milk yields may increase with increasing time after conversion from IP to OP, this is a gradual process because OP farms in our study had converted to OP on average 6 yr earlier, but the OP cows still produced less milk than those on IP farms. Genetic and nongenetic factors were found to influence milk yield in this study. The interaction of genetic and nongenetic factors with the changed environment after conversion from IP to OP seems to have a negative impact on milk production.

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