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Association between Hygienic Milk Quality and Culling Rate or Mortality in Dairy Herds: A Cross-Sectional Study in Eastern Hokkaido, Japan

Akira GOTO[1,2], Mitsuo YOKOI[3], Naoki YAMAMOTO[1], Kenji KUTARA[1], Yoichi INOUE[1], Keiichi HISAEDA[1], Yasunori SHINOZUKA[1] and Ken NAKADA[4]*

[1] Department of Veterinary Medicine, Faculty of Veterinary Medicine, Okayama University of Science, Imabari, Japan
[2] Department of Veterinary Medicine, Obihiro University of Agriculture and Veterinary Medicine, Obihiro, Japan
[3] Yotsuba Milk Products, Otofuke, Hokkaido, Japan
[4] Department of Veterinary Medicine, School of Veterinary Medicine, Rakuno Gakuen University, Ebetsu, Japan

Abstract

This study analyzed production records from Hokkaido, Japan to develop a plan for farmers to improve milk quality. Over three years, 164 dairy herds were evaluated based on two milk quality indices: herd-level somatic cell count and chronic subclinical mastitis morbidity. Farms were ranked annually for each index, and the rankings were combined to determine an overall evaluation. After a comprehensive assessment, the herds were categorized into three groups: excellent (36 herds), good (90 herds), and poor (38 herds). A comparative analysis of nine production indices, including milk quality, was conducted between the excellent and poor groups. Our study revealed that poor herds exhibited significantly smaller herd sizes, higher culling rates at specific periods, higher mortality, and a greater proportion of dead cows among culled cows than excellent herds. The increased mortality in poor herds suggests lower animal welfare standards. Furthermore, the high rate of involuntary culling indicates suboptimal peripartum management. These findings underscore the strong link between poor milk quality and compromised animal welfare. The results suggest that improving animal welfare practices can lead to higher milk quality in dairy herds.

Discipline: Animal Science
Additional key words: animal welfare, somatic cell count

Introduction

The milk somatic cell count (SCC) is a standard index for detecting inflammation in dairy cows, particularly in the diagnosis of mastitis, and serves as a proxy for measuring the neutrophil concentration in milk (Pisanu et al. 2019). A recent global downward trend in herd SCC has been observed (Barkema et al. 2013). Herd-level SCC has not improved in Hokkaido, Japan, where it has stalled at around 220,000 cells/ml for the past decade (LIAJ 2020). An increased herd SCC above 200,000 cells/ml is typically produced by the influx of milk with high SCC from cows affected by mastitis within the herd (Barbano et al. 2006).

Hokkaido, Japan, is well known for its dairy production, with Eastern Hokkaido being particularly active in dairy farming. Government statistics show that udder disease is the most common among dairy cows in Hokkaido, accounting for 36.5% of all diseases (MAFF 2017). It is the second most common reason after death for culling, making udder disease a big concern in the Hokkaido dairy industry (LIAJ 2020). Mastitis prevention is essential for good milk quality and improving the profitability of dairy herds. However, in clinical practice, the risk factors for mastitis are diverse. Accurately identifying risk factors and using a systematic strategy

*Corresponding author: kenn@rakuno.ac.jp
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are critical to correctly solving the mastitis problem. Remedial actions will not be successful unless the underlying cause is found (Barkema et al. 2013). Several reviews have evaluated mastitis management, including milking hygiene and barn environmental management in dairy herds, and have emphasized the importance of animal welfare in improving milk quality (Barkema et al. 2013, Cheng & Han 2020, Ruegg 2017). Food animal management that incorporates animal welfare has been required worldwide, and improved animal welfare in dairy herds can increase profitability (WOAH 2023). The relationship between cow mortality and animal welfare has been described in studies on farm management in dairy herds. Cow mortality is a reliable indicator of animal welfare in dairy management (Thomsen & Houe 2018).

To improve milk quality, dairy farmers and advisors need to understand the situation in actual practice to identify the most effective steps to take. However, no previous observational studies have described the situation in Japanese dairy farms and provided strategies to address the problems. Therefore, although our group published the first observational study on longevity and milk quality in dairy herds (Goto et al. 2024), further study is required to improve milk quality in Hokkaido. In clinical and epidemiological studies using large datasets, it is accepted practice (Kassirer & Angell 1995) to report the results of analyses performed on the same dataset separately but with different aims and hypotheses, and indeed, there are precedents (Kato et al. 2015, Kato et al. 2019). If the results of this study can help solve clinical problems, dairy farmers and their advisors can adopt evidence-based strategies. Additionally, targeted interventions, such as those on farms with significant issues, could greatly improve productivity.

This study conducted an epidemiological analysis using production records from the same database employed in a previous study (Goto et al. 2024). While the previous study investigated the causal relationship between herd longevity and milk quality, the present study categorized herds into three groups (excellent: 36 farms; good: 90 farms; and poor: 38 farms) based on milk quality indices. Using the excellent farms within the same region as benchmarks for the poor farms, we objectively assessed the status of the poor farms by comparing multiple productivity indices, including milk quality. This benchmarking approach aims to quantify the performance gap between poor and good farms, identify key areas for improvement, and ultimately facilitate more effective intervention strategies. The overall objective of this study is to support poor farms in developing and implementing improvement plans to enhance their productivity by adopting best practices from excellent farms.

Materials and methods

This study did not evaluate live animals but instead analyzed stored milk production records. Therefore, ethical approval for animal experiments was not required.

This study analyzed the DHI records collected by the Hokkaido Dairy Milk Recording and Testing Association. The production data included 168 dairy herds comprising 874,771 cows in the Shikaoi, Shihoro, and Kitami regions of Eastern Hokkaido, Japan, with continuous subscriptions to DHI from April 1, 2018 to March 31, 2021. Thirty-six tests were conducted monthly during the study period. Subsequently, four expanding farms with a coefficient of variation (standard deviation per average) exceeding 20% of the average number of cows raised during the study period were excluded from the analysis. Ultimately, 164 herds were eligible for inclusion in the study. The median number of cows in these herds was 95 (interquartile range, 66-170).

Various productivity indices were compared by herd milk quality. The variables for evaluating milk quality in the herd included herd-level SCC and chronic subclinical mastitis (CSM) morbidity. To calculate the herd SCC, the total SCC of each cow was first determined by multiplying the individual SCC by the individual milk yield. The herd SCC was then calculated as the sum of the total SCC of each cow divided by the total milk yield of the herd. The annual median value obtained during the analysis was used as the representative value for the herd and calculated for each fiscal year.

To calculate CSM morbidity, an SCC of 200,000/ml or higher was defined as subclinical mastitis (Barkema et al. 2013, Martins et al. 2020). In addition, cows with subclinical mastitis having an SCC of 200,000/ml or more in the previous and current months and persisting for two consecutive months were classified as having CSM (Barkema et al. 2013, Martins et al. 2020). CSM morbidity was calculated as the monthly ratio of CSM cows to the total number of cows. The annual median value obtained was used as the representative value for the herd and was calculated for each fiscal year. All 164 dairy herds were ranked annually for each herd SCC and CSM morbidity from 2019 to 2021. Then, rankings for herd SCC and CSM morbidity for every year were combined to calculate a comprehensive milk quality score for the annual year, and herds were re-ranked based on this overall score. Subsequently, the herds were divided into four groups by quartile. The top 25% of herds received 0 points, the next 25% received 1 point, and so on, up to 3 points. A three-year cumulative score was calculated by summing the points earned by each herd over the three years. Herds with a three-year cumulative score between 0 and 1 were categorized as having "Excellent" milk quality (EX-G), indicating consistently high milk quality over the three years. This included farms that ranked in the top 25% in all years or the top 25%-50% in some years. Conversely, herds with a cumulative score between 8 and 9 were categorized as having "Poor" milk quality (POOR-G), indicating chronically low milk quality over the three years. These farms consistently ranked in the bottom 25% in all years or the bottom 25%-50% in some years. Herds with a cumulative score between 2 and 7 were categorized as having "Good" milk quality (GOOD-G).

The other seven production indices used were the 2020 records for the number of cows, rate of cows with four or more parities, culling rate (voluntary and involuntary culling), culling rate within 60 days after calving, culling rate within 200 days after calving, mortality, and dead cows per culled cows. The number of cows was used as an indicator of the management scale, and the rate of cows with four or more parities was used to indicate longevity (Goto et al. 2024). The number of cows and the rate of cows with four or more parities were calculated monthly, the annual median of which was used as the representative value. The culling rate and mortality were calculated annually for each fiscal year. The DHI dataset used in this study does not provide a reason for culling; therefore, it could not differentiate between voluntary (such as cow resale to other farms) and involuntary (such as infertility) culling. The index of dead cows per culled cow was calculated by dividing the number of dead cows by the total number of culled cows, including both voluntary and involuntary.

Summary statistics were calculated for all production indices according to milk quality categories. The normality of the distribution of all production indices was tested using the Kolmogorov-Smirnov test. The Wilcoxon test was used to compare each index between EX-G and POOR-G. Chi-squared tests were conducted for comparisons among the three groups (EX-G, GOOD-G, and POOR-G), with multiple comparisons adjusted using the Bonferroni method. P values < 0.05 were considered statistically significant. All statistical analyses were performed using SAS version 9.4 (SAS Institute Japan Ltd., Tokyo, Japan).

Results

Table 1 is a 2020 summary of the nine production indices calculated by classifying dairy herds into EX-G, GOOD-G, and POOR-G, based on cumulative milk quality over the three-year study period. The normality test confirmed that the indices were not normally distributed. Table 2 compares each production index for fiscal year 2020 using the Wilcoxon test between the EX-G and the POOR-G groups. Significant differences were observed in the following indices: herd SCC, CSM morbidity, number of cows, culling rate within 60 days after calving, culling rate within 200 days after calving, mortality, and dead cows per culled cows. In contrast, no significant differences were found in the rate of cows with four or more parities and the culling rate between the two groups. Table 3 compares the distribution of dairy herds by milk quality category per region. The EX-G and GOOD-G herd distributions showed no regional differences; however, Region B had a much higher proportion of POOR-G herds than the other regions.

Discussion

The analysis showed that EX-G herds have more cattle and thus a larger herd size than POOR-G herds. This result agrees with previous studies (Oleggini et al. 2001). Conversely, some reports have associated increasing herd size with increasing SCC (Archer et al. 2013), and no consensus has been reached on the relationship between herd size and milk quality. Schewe et al. (Schewe et al. 2015) reported that multiple factors, such as differences in cowsheds, milking environments, farm labor, and farm workers, influence the relationship between herd size and milk quality. In Eastern Hokkaido, smaller farms have significantly poorer milk quality than larger farms; thus, providing production support according to farm size may improve milk quality.

Significant differences were found in culling rates within 60 and 200 days after calving between the EX-G and POOR-G. Culling rates within 60 days after calving are a measure of on-farm peripartum management (Fetrow et al. 2006, Goto et al. 2019), with most culling occurring within 60 days after calving (Hadley et al. 2006). The culling rate within 60 days after calving was significantly higher in the POOR-G group than in the EX-G group, which suggests that appropriate peripartum management was not upheld in the POOR-G group. Dairy cows are susceptible to mastitis immediately after calving and during the first month of lactation. This increased susceptibility is primarily attributed to immunosuppression caused by the stress of calving (Cheng & Han 2020). Therefore, improving peripartum management may improve milk quality in POOR-G herds. Days in milk (DIM) indicate the number of days a cow has been milking in her current lactation, the same

Table 1. Summary statistics of production indexes by milk quality herds for 2020

Herd category	Number of herds	Variable	Mean	Std. Dev.	Min	Max	Lower quartile	Median	Upper quartile
Excellent	36	Herd SCC	99.3	31.3	42.3	168.5	80.0	98.3	119.1
		CSM morbidity	0.04	0.02	0.00	0.09	0.03	0.04	0.06
		Number of cows	172.0	181.3	27.9	949.2	81.1	94.2	190.7
		Rate of cows with 4 or more parities (≥ 4)	0.22	0.09	0.12	0.64	0.16	0.20	0.26
		Culling rate	0.32	0.10	0.16	0.58	0.25	0.31	0.39
		Culling rate within 60 days after calving	0.08	0.05	0.00	0.30	0.05	0.07	0.10
		Culling rate within 200 days after calving	0.16	0.07	0.05	0.40	0.11	0.14	0.18
		Mortality	0.03	0.03	0.00	0.14	0.02	0.03	0.04
		Dead cows per culling cows	0.11	0.10	0.00	0.46	0.06	0.08	0.13
Good	90	Herd SCC	178.1	45.7	75.1	307.8	150.0	169.1	202.5
		CSM morbidity	0.11	0.04	0.04	0.24	0.08	0.10	0.13
		Number of cows	147.9	135.7	23.5	1059.7	73.9	126.0	177.4
		Rate of cows with 4 or more parities (≥ 4)	0.21	0.08	0.09	0.55	0.16	0.20	0.24
		Culling rate	0.31	0.09	0.06	0.74	0.27	0.30	0.34
		Culling rate within 60 days after calving	0.08	0.04	0.00	0.26	0.06	0.08	0.10
		Culling rate within 200 days after calving	0.16	0.06	0.02	0.39	0.12	0.15	0.19
		Mortality	0.06	0.06	0.00	0.48	0.02	0.05	0.09
		Dead cows per culling cows	0.20	0.16	0.00	0.67	0.08	0.16	0.30
Poor	38	Herd SCC	322.9	101.2	179.5	640.7	249.1	300.6	365.5
		CSM morbidity	0.20	0.06	0.09	0.39	0.15	0.20	0.22
		Number of cows	101.8	70.5	17.9	300.8	55.2	78.9	146.9
		Rate of cows with 4 or more parities (≥ 4)	0.24	0.12	0.09	0.56	0.16	0.21	0.29
		Culling rate	0.37	0.14	0.15	0.79	0.27	0.36	0.39
		Culling rate within 60 days after calving	0.11	0.06	0.00	0.22	0.07	0.09	0.16
		Culling rate within 200 days after calving	0.20	0.11	0.00	0.52	0.14	0.16	0.25
		Mortality	0.12	0.06	0.00	0.31	0.08	0.12	0.16
		Dead cows per culling cows	0.36	0.17	0.00	0.75	0.23	0.35	0.45

Std. Dev.: standard deviation; SCC: somatic cell count (×103 cells/mL); CSM: chronic subclinical mastitis

Table 2. Comparison of production indices between excellent and poor milk quality herds in 2020 by the Wilcoxon test

Variable	*P* value
Herd SCC	< 0.0001
CSM morbidity	< 0.0001
Number of cows	0.0167
Rate of cows with 4 or more parities (≥ 4)	0.7670
Culling rate	0.2196
Culling rate within 60 days after calving	0.0085
Culling rate within 200 days after calving	0.0462
Mortality	< 0.0001
Dead cows per culling cows	< 0.0001

SCC: somatic cell count (×10^3 cells/mL); CSM: chronic subclinical mastitis

Table 3. Distribution of the herds according to the milk quality herds in each area

Area	n	Number of herds (%)		
		Excellent	Good	Poor
A	75	19 (25.3)	47 (62.7)	9 (12.0)
B	63	9 (14.3)	28 (44.4)	26 (41.3) **
C	26	8 (30.8)	15 (57.7)	3 (11.5)

**$P < 0.01$: chi-squared test in the same column

measurement as days since fresh. DIM 200 indicates productivity; dairy cows below DIM 200 are at a stage of lactation where sufficient milk production and profit can be expected, whereas cows above DIM 200 are indicative of reproductive problems (Boztepe & Aytekin 2017). The culling rate within 200 days after calving was significantly higher in the POOR-G than in the EX-G herds. In addition, the most common cause for culling in Hokkaido is death, followed by udder disease, other diseases (locomotor, digestive, for example), reproductive disease, and resale for milk production (LIAJ 2020). Thus, cows in POOR-G herds may be culled because of involuntary death, udder disease, and other diseases.

Compared to the EX-G group, the POOR-G group had much higher mortality rates and dead cows per culled cow. Animal welfare is related to higher herd mortality, a reliable metric of animal welfare (Thomsen & Houe 2018). In addition, the high involuntary culling rate in the herd indicates poor animal welfare and inefficient animal management (Ahlman et al. 2011). Environmental and herd management significantly impacts animal health and welfare, which is associated with the risk of mastitis. Infection and severity of mastitis tend to decrease in dairy herds kept in hygienic, pleasant conditions (Cheng & Han 2020).

No differences were found between the EX-G and POOR-G groups in the rate of cows with four or more parities and the culling rate, so there were no differences in the proportion of older multiparous cows and the annual culling rate. However, significant differences were noted between the two groups regarding the culling rate at a specific period, mortality, and mortality due to culling. In the EX-G group, most culling decisions were voluntary, indicating that the herds would be composed of higher-quality dairy cows. Conversely, most of the culling in the POOR-G group was involuntary, and the herds mostly consisted of dairy cows that were less profitable due to the reduced selection pressure in the herd.

Table 3 shows that Region B had more POOR-G herds than the other regions. Previous studies have already discussed the differences in milk quality between areas (Ely et al. 2003). Varying levels of awareness among producers and regional production support systems may fundamentally cause variations in milk quality between areas. Farmers in areas with organizations working to improve productivity, such as dairy cooperatives, are provided a wider range of support and have higher production awareness. However, farmers in places with little support have limited knowledge and options. To improve milk quality throughout Hokkaido, regional investment in support resources and systems may significantly improve milk quality.

The following limitations should be considered when interpreting the data obtained in this study. First, the data were predominantly collected from DHI subscribers; hence, the sample population may not fully represent all farms within the study area. Second, the period for collecting samples (three years) might have been short, and disease occurrence and productivity may not be constant each year in dairy herds. Moreover, this study employed a cross-sectional design at the herd level that could limit the generalizability of the results. Longitudinal studies at the cow level will be necessary to gain additional insight into the effects of animal welfare and peripartum management on milk quality. Further research with a larger dataset, such as covering the entire Hokkaido area over a long period, is necessary to verify the findings and enhance the current understanding of this subject matter.

Conclusion

This epidemiological analysis of DHI records in Hokkaido found that the POOR-G and EX-G groups varied significantly in herd size, culling rate at a specific period, mortality, and dead cows per culling cow. The results suggest that improved peripartum management and animal welfare may improve milk quality. Furthermore, the high culling rate in the POOR-G group was primarily due to involuntary culling; thus, the dairy cows in such herds would have lower profitability due to the lower selection pressure within the herds. Improving milk quality in line with regional targets will be essential in the future.

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Conflict of Interest Statement

The authors declare no conflicts of interest associated with this manuscript.

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