

The association of culling and death rate within 30 days after calving with productivity or reproductive performance in dairy herds in Fukuoka, Southern Japan

Akira GOTO¹⁾, Ken NAKADA²⁾ and Hiromu KATAMOTO^{1,3)*}

¹⁾Graduate School of Medicine and Veterinary Medicine, University of Miyazaki, 5200, Kihara, Kiyotake, Miyazaki 889–1692, Japan

²⁾Division of Health and Environmental Sciences, School of Veterinary Medicine, Rakuno Gakuen University, 582, Bunkyo-dai-Midorimachi, Ebetsu, Hokkaido 069–8501, Japan

³⁾Department of Veterinary Sciences, Faculty of Agriculture, University of Miyazaki, 1–1, Gakuen Kibanadai-nishi, Miyazaki 889–2192, Japan

(Received 25 September 2015/Accepted 30 November 2015/Published online in J-STAGE 14 December 2015)

ABSTRACT. The incidence of peripartum disorders in dairy herds negatively influences productivity and reproductive performance. Concrete data from local areas are helpful for explaining the importance of peripartum management to dairy farmers. This study was conducted to clarify the association of culling and death rate within 30 days after calving with productivity or reproductive performance in 179 dairy herds in Fukuoka, Southern Japan. A database was compiled from the records of the Livestock Improvement Association of Japan, the Dairy Cooperative Association and the Federation of Agricultural Mutual Relief Association. In this study, we created a comprehensive database of dairy farm production data for epidemiological analysis and used a general linear mixed model to analyze the association of culling and death rate within 30 days after calving with milk production or reproductive performance. The database can be used to describe, analyze and predict the risk of production. A cross-sectional analysis with contrasts was applied to investigate the association of cows served by AI/all cows, pregnant cows/cows served by AI, days open, milk yield and somatic cell counts with culling and death rate within 30 days after calving. The days open value significantly increased with increasing rate of culling and death within 30 days after calving (P for trend <0.001). No significant differences were found for the other comparisons. Our data suggest that proper feeding and management in the dry period may lead to improved postpartum reproductive performance in this dairy cow cohort.

KEY WORDS: dairy herd, epidemiological analysis, peripartum period, productivity, reproductive performance

doi: 10.1292/jvms.15-0554; *J. Vet. Med. Sci.* 78(4): 587–592, 2016

Many variables can differ in dairy farming, including animal housing environment, self-supplied feed, forage and herd size. Dairy herd productivity and reproductive performance are influenced by many environmental factors, such as climate and geography [3, 9]. The Japanese archipelago stretches from north to south and has a few different climatic zones, from the subtropical areas of the south to the subarctic areas of the north. The environment of Japanese dairy farming greatly varies according to the area. Therefore, it is important to take each area's characteristics and farming background into consideration and break down the regional information when using the data to improve dairy farming in each specific region. LeBlanc *et al.* [13] reported that epidemiology is central for demonstrating and quantifying the interrelated nature of the most common diseases in dairy cattle. Koketsu [11] reported that in order to control production, it is essential for the decision to be made based on evidence from the production record. Epidemiological observational studies are suitable for the analysis of factors that hinder productivity or reproductive performance [18].

Japanese dairy farmers have the plurality of information that is separately managed by several organizations. The Dairy Cooperative Association manages herd-level productivity information, while the Livestock Improvement Association of Japan (LIAJ) manages cow-level productivity and reproductive information. Lastly, the Federation of Agricultural Mutual Relief Association manages disease information of individual cattle. These pieces of information have not yet been integrated. In Europe and the U.S.A., integrated databases are also being analyzed and studied for disease prevention [12, 20]. Therefore, databases are required for centralization of information and secondary use of this information when aiming to clarify risk factors and associations between these factors in dairy farming. If unification of these records is enabled, specific connections between diseases and production or reproductive performance could be made.

We planned this epidemiological observational study using existing information to identify our field problems and to increase dairy productivity. In particular, we focused on clarifying the importance of management during dry period. The incidence of the common clinical disease in dairy cows is closely associated with calving, and the high risk period is within the 30 days after calving. This study specifically focused on monitoring the incidence rate of cow diseases during the early postpartum period [5, 21].

The objective of this study was therefore to test the hypothesis that productivity and reproductive performance are low in dairy herds with a high rate of culling and death within 30 days after calving in Fukuoka, Southern Japan,

*CORRESPONDENCE TO: KATAMOTO, H., Department of Veterinary Sciences, Faculty of Agriculture, University of Miyazaki, 1–1, Gakuen Kibanadai-nishi, Miyazaki 889–2192, Japan.
e-mail: katamoto@cc.miyazaki-u.ac.jp

©2016 The Japanese Society of Veterinary Science

This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License <<http://creativecommons.org/licenses/by-nc-nd/4.0/>>.

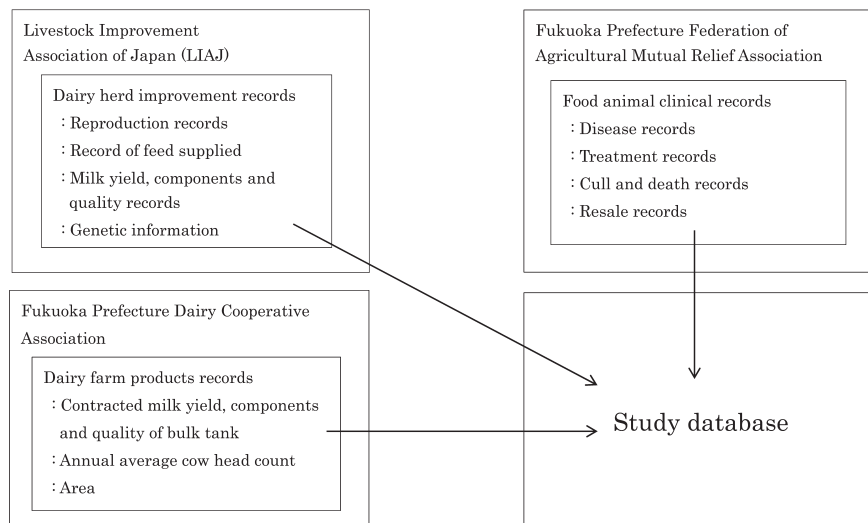


Fig. 1. The study database of the dairy herds was created from data from three different associations.

using a cross-sectional study design.

MATERIALS AND METHODS

Study area: Fukuoka (coordinates: 33°35'N 130°24'E) is a prefecture in Kyushu, a large island in Southern Japan. Fukuoka has a subtropical climate with humid summers and relatively mild winters. There were 19,400 dairy farms in Japan, and 274 of these were in Fukuoka, in which 15,800 dairy cows were raised, and the ratio among the whole country was 1.1% [16].

Data collection: This study was carried out in accordance with the guidelines for the care and use of laboratory animals at the University of Miyazaki. Records from dairy farms from April 1, 2012 to March 31, 2013 were used for the analysis. During the investigation period, records from the LIAJ, Dairy Cooperative Association and Federation of Agricultural Mutual Relief Association were available for 179 farms out of the 274 dairy farms in the area. As shown in Fig. 1, the LIAJ records included monthly data on reproduction record, milk yield, milk components, quality testing, quality of feed supplied and feeding state. The Dairy Cooperative Association records included information on milk fat, protein, somatic cell counts, milk urea nitrogen of bulk tank and contracted milk yield for each month; these data were obtained twice a month. Furthermore, the annual average dairy cow head count was obtained based on a survey conducted twice a year, and every individual number of milk collection station was used to identify the local area. The Federation of Agricultural Mutual Relief Association records included data on any diseases diagnosed by a veterinarian. All cows had a 10-digit individual identification number (National Livestock Breeding Center), and the data from three different associations were integrated using the individual identification number or the farm name.

Data processing: The data were converted into a suitable

form for computer processing. In the LIAJ records, the annual medians of monthly number or monthly mean value of calving interval, days open, parity, number of calved cows, number of artificial inseminations (AI) or embryo transfers, and number of pregnant cows were used as representative figures for the farms. In the Dairy Cooperative Association records, the averages of two values of component and quality of the bulk tank in a month were calculated, and these annual medians were used as representative figures for the farms. Furthermore, the annual median individual milk yield per day was calculated from the contracted milk yield and annual average head count of the cows. In the Federation of Agricultural Mutual Relief Association records, the morbidity and culling and death rate within 30 days after calving were estimated based on the number of calved cows. Furthermore, the mean annual morbidity and culling rates were calculated. In this study, culling was defined as involuntary culling that included culling due to disease or injury and did not include voluntary one due to infertility disease or sale for use as dairy animals or slaughtering, because the data from the Federation of Agricultural Mutual Relief Association were classified into disease categories in accordance with the categories used for the agricultural disaster indemnity. Moreover, culling rate was calculated by dividing the sum of involuntary and voluntary culled cow counts by the total number of cows. All calving date information was obtained and confirmed from the LIAJ and calf birth records.

Statistical analysis: All statistical analyses were conducted with SAS software (ver 9.4; SAS Institute Inc., Cary, NC, U.S.A.). The outcomes were described using summary statistics. A general linear mixed model using the GENMOD procedure with contrasts was applied to investigate the association of cows served by AI/all cows, pregnant cows/cows served by AI, days open, milk yield and somatic cell counts with culling and death rate within 30 days after calving. A $P < 0.05$ was regarded as statistically significant.

Table 1. Characteristics of production, disease and reproduction in Fukuoka dairy herds

	Number of farms	Lower quartile	Median	Upper quartile
Number of cows	179	27	37	50
Milking cows/all cows ^{a)} (%)	179	83.6	86.2	88.3
Individual milk yield per day (kg)	179	24.7	27.4	29.4
Milk fat of bulk tank (%)	179	3.79	3.88	3.96
Milk protein of bulk tank (%)	179	3.22	3.28	3.34
Average somatic cell counts of bulk tank ($\times 10^3$ /ml)	179	170	209	243
Milk urea nitrogen of bulk tank (mg/dl)	179	11.7	13.0	14.1
Morbidity within 30 days after calving (%)	179	28.6	41.2	55.2
Culling and death rate within 30 days after calving (%)	179	1.2	3.7	6.7
Culling rate (%)	179	21.7	26.1	33.8
Calving interval (days)	178	427	445	470
Days open (days)	177	154	177	206
Average parity	178	2.4	2.7	2.9
Calved cows/all cows ^{a)} (%)	179	80.5	89.7	96.3
Cows served by AI/all cows ^{a)} (%)	179	69.4	74.3	77.7
Pregnant cows/cows served by AI (%)	178	57.7	62.1	66.2

a) Mean total number of cows during the study period.

RESULTS

As shown in Table 1, the mean number of cows was 37 in Fukuoka dairy farms, whereas the national mean was less than 47 cows [16]. Thus, in Fukuoka, the mean herd size was comparatively smaller than those in other areas in Japan. From disease and injury as well as culling and death profiles in Fukuoka dairy farm, reproductive diseases occurred most commonly throughout the year (Table 2). Common diseases within 30 days after calving included perinatal (43.5%), metabolic (18.9%) and udder diseases (17.6%). The most common reasons for culling and death within 30 days after calving were perinatal (31.3%), locomotive (19.0%) and udder diseases (17.6%). The percentage of locomotive diseases in culling and death increased compared with the morbidity. The number of cows presented to veterinarians and culled for locomotive diseases was 110 and 54, respectively, showing that nearly half of cows with locomotive disorders within 30 days after calving were culled. In Table 2, we used the same classification criteria for the diseases as those used by the Federation of Agricultural Mutual Relief Association. The main diseases in each category were ovarian or uterine diseases in the reproductive category, mastitis or teat injury in the udder category, milk fever or downer cows in the perinatal category, abomasal displacement or gastric flatulence in the digestive category, muscular injury or hoof diseases in the locomotive category, and ketosis or amyloidosis in the metabolic category.

The productivity and reproductive performance outcomes for each variable are shown in Tables 3 and 4, respectively. Eight items were assigned as the independent variables. The stall type and area were sorted into three category groups, whereas all other variables were sorted into four category groups based on the quartiles. Culling and death rate within 30 days after calving was considered as a representative event that reflected feeding management during the dry period in herds and was divided into four groups based on the quartiles (<1.23%, 1.23–3.70%, 3.71–6.66%, >6.66%). The numbers

Table 2. List of diseases and reasons for culling and death in Fukuoka dairy herds from April 1, 2012 to March 31, 2013

	Disease categories	% (n/N)
Diseases during study period	Reproductive	33.1 (3,688/11,137)
	Udder	23.0 (2,563/11,137)
	Perinatal	13.4 (1,487/11,137)
	Digestive	11.1 (1,240/11,137)
	Locomotive	8.4 (940/11,137)
	Others	10.9 (1,219/11,137)
Diseases within 30 days after calving ^{a)}	Perinatal	43.5 (1,212/2,788)
	Metabolic	18.9 (526/2,788)
	Udder	17.6 (490/2,788)
	Digestive	12.4 (346/2,788)
	Locomotive	3.9 (110/2,788)
	Others	3.7 (104/2,788)
Culling and death within 30 days after calving	Perinatal	31.3 (89/284)
	Locomotive	19.0 (54/284)
	Udder	17.6 (50/284)
	Digestive	13.4 (38/284)
	Cardiovascular	8.5 (24/284)
	Others	10.2 (29/284)

a) The numbers of cows with each type of disease include those from culling and death.

of farms in the groups were 44, 42, 52 and 41, respectively. The mean days open was one of the outcomes, which increased with an increase in the culling and death rate.

The associations between culling and death rate within 30 days after calving and five outcomes assessed by the cross-sectional analysis are shown in Table 5. The group with the lowest culling and death rate was considered as the reference group. The estimated days open was significantly higher in the three other groups with higher culling and death rate compared with the reference group ($P < 0.05$). Moreover, the days open significantly increased with increasing culling and death rate within 30 days after calving (P for trend < 0.001).

Table 3. Productivity outcomes in the category groups for each variable

Variable	Category groups	Milk yield ^{a)}			SCC ^{b)}		
		N	Mean	SD	N	Mean	SD
Culling and death rate within 30 days after calving (%)	<1.23	44	26.5	4.4	44	206	54
	1.23–3.70	42	28.6	3.9	42	203	52
	3.71–6.66	52	27.8	3.2	52	207	59
	>6.66	41	25.5	3.3	41	204	61
Stall type	Tie stall	144	26.8	3.9	144	199	58
	Free stall	12	29.3	2.4	12	226	31
	Free barn	23	28.2	3.9	23	230	44
Herd size	<27	44	25.1	4.1	44	190	65
	27–36	42	26.0	3.0	42	208	52
	37–49	48	28.2	3.5	48	202	54
	>49	45	29.0	3.5	45	221	51
Milk yield ^{a)}	<24.7	44	22.3	2.5	44	221	60
	24.7–27.3	45	25.9	0.8	45	205	56
	27.4–29.4	45	28.5	0.6	45	196	56
	>29.4	45	31.8	1.8	45	198	51
SCC ^{b)}	<170	44	28.2	4.0	44	132	29
	170–208	45	27.5	3.4	45	187	10
	209–243	45	26.8	4.0	45	225	11
	>243	45	26.1	3.8	45	274	29
Area	Northwest	52	28.5	3.4	52	218	58
	Northeast	89	26.9	3.7	89	200	56
	South	38	25.8	4.4	38	199	53
Parity	<2.4	34	26.0	4.3	34	204	53
	2.4–2.6	46	28.4	3.2	46	206	48
	2.7–2.9	41	27.7	3.9	41	200	65
	>2.9	58	26.4	3.8	58	208	59
Morbidity per year (%)	<106	44	27.8	3.9	44	202	48
	106–136	44	26.7	3.6	44	208	60
	137–178	45	27.6	3.8	45	210	59
	>178	46	26.5	4.1	46	200	58

a) Milk yield per cow per day (kg). b) Somatic cell counts in bulk tank milk ($\times 10^3/m^l$).

The culling and death rate within 30 days after calving did not affect the other outcomes of productivity and reproductive performance in this study.

DISCUSSION

In this study, the main diseases within 30 days after calving were perinatal, metabolic and udder diseases, while the most common reasons for culling and death were perinatal, locomotive and udder diseases. These results were consistent with previous reports [10, 19]. It was supposed that the increased rate of locomotive diseases was attributed to secondary recumbency caused by dislocation or muscular injury following Downer cow syndrome [15]. Since Downer cow syndrome is considered to be a complication of parturient hypocalcemia, dietary managements preventing milk fever were suggested to be important to decrease the culling and death rate in perinatal and locomotive diseases within 30 days after calving.

We collated dairy production and clinical data from three different cooperative organizations and integrated their data to analyze the regional situation of dairy herds in Fukuoka, Southern Japan. We compiled a database to analyze the asso-

ciations between factors of interest and production problems. This analysis of the integrated data allowed us to elucidate the present conditions in 179 farms out of 274 dairy farms in this area. However, this integrated database using data from the three organizations was limited, because the final data only included those from 65% of the dairy farms in this area. This limitation is due to the lower joining rate of LIAJ than that of the other two cooperative organizations. Additionally, most of the participants were those farms that were interested in genetic improvement of their dairy herds (Fig. 1). Therefore, the results may be affected by selection bias of the farms.

We found no associations between productivity outcomes and the explanatory variable, which was culling and death rate within 30 days after calving (Table 3). However, we found an association between the days open, one of the reproductive performance outcomes and the explanatory variable (Table 4). We performed a multivariable analysis with adjustment for confounding factors, which also demonstrated that the days open significantly increased with increasing culling and death rate within 30 days after calving (P for trend <0.001) (Table 5). These results show that dairy herds with a high culling and death rate within 30 days after calving had long days open in this area. Most disorders

Table 4. Reproductive performance outcomes in the category groups for each variable

Variable	Category groups	Cows served by AI/all cows ^{a)} (%)			Pregnant cows/cows served by AI (%)			Days open		
		N	Mean	SD	N	Mean	SD	N	Mean	SD
Culling and death rate within 30 days after calving (%)	<1.23	44	70.0	14.7	43	61.2	7.8	42	168	38
	1.23–3.70	42	70.9	13.7	42	64.3	10.2	42	177	36
	3.71–6.66	52	73.4	6.6	52	61.0	6.6	52	181	39
	>6.66	41	72.7	7.6	41	64.5	9.1	41	205	44
Stall type	Tie stall	144	72.0	10.1	143	62.0	7.8	143	185	42
	Free stall	12	74.0	6.3	12	62.0	5.6	12	180	30
	Free barn	23	70.0	17.3	23	66.6	12.3	22	171	34
Herd size	<27	44	69.3	14.8	43	61.4	8.1	43	187	50
	27–36	42	74.4	7.2	42	61.0	10.2	41	198	44
	37–49	48	72.9	6.6	48	62.4	5.3	48	175	32
	>49	45	70.9	13.1	45	65.5	9.4	45	173	33
Milk yield ^{b)}	<24.7	44	70.4	15.0	44	63.6	8.9	43	193	48
	24.7–27.3	45	72.0	7.3	45	63.5	8.8	45	182	41
	27.4–29.4	45	71.0	13.1	44	61.1	9.7	44	184	40
	>29.4	45	73.9	6.7	45	62.3	6.3	45	173	32
SCC ^{c)}	<170	44	69.8	14.4	43	61.6	7.6	43	180	41
	170–208	45	73.2	7.8	45	61.9	9.0	45	185	38
	209–243	45	74.4	7.3	45	62.9	8.9	44	177	33
	>243	45	70.0	12.8	45	64.1	8.5	45	189	50
Area	Northwest	52	72.6	8.3	52	63.1	5.7	52	173	40
	Northeast	89	70.9	13.2	88	63.2	10.2	88	186	40
	South	38	73.0	8.8	38	60.7	7.1	37	188	42
Parity	<2.4	34	66.2	18.9	33	64.0	10.6	32	198	42
	2.4–2.6	46	73.6	6.0	46	62.1	8.6	46	183	32
	2.7–2.9	41	73.3	9.9	41	62.2	5.3	41	166	41
	>2.9	58	72.8	7.5	58	62.6	9.1	58	186	43
Morbidity per year (%)	<106	44	70.2	12.7	44	62.2	10.6	44	177	32
	106–136	44	70.4	13.6	43	61.4	9.2	42	188	47
	137–178	45	71.7	11.1	45	64.6	7.7	45	183	41
	>178	46	74.9	4.4	46	62.2	5.9	46	183	43

a) Mean total number of cows during the study period. b) Milk yield per cow per day (kg). c) Somatic cell counts in bulk tank milk ($\times 10^3/m$).

Table 5. The associations between the culling and death rate within 30 days after calving and different outcomes assessed in this cross-sectional study

Dependent variable	Culling and death rate within 30 days after calving (%)				P for trend	
	<1.23	1.23–3.70	3.71–6.66	>6.66		
Cows served by AI/all cows ^{a)} (%) ^{b)}	Estimate value	Reference	0.062	3.310	3.807	0.044
	95% CI ^{c)}		(–4.895–5.020)	(–0.902–7.521)	(–0.710–8.324)	
Pregnant cows/cows served by AI (%) ^{b)}	Estimate value	Reference	1.401	–1.277	2.507	0.405
	95% CI		(–2.537–5.334)	(–4.635–2.080)	(–1.096–6.111)	
Days open ^{b)}	Estimate value	Reference	24.769*	19.819*	32.061*	<0.001
	95% CI		(6.936–42.601)	(4.622–35.015)	(15.809–48.313)	
Milk yield ^{d, e)}	Estimate value	Reference	–0.186	–0.020	–1.015	0.408
	95% CI		(–1.749–1.377)	(–1.344–1.304)	(–2.429–0.399)	
SCC ^{f, g)}	Estimate value	Reference	–17.843	–5.512	–3.749	0.543
	95% CI		(–43.224–7.538)	(–27.328–16.305)	(–27.015–19.517)	

a) Mean total number of cows during the study period. b) Adjusted by seven variables: stall type, herd size, milk yield, SCC, area, parity and morbidity per year. c) Confidence interval. d) Milk yield per cow per day (kg). e) Adjusted by six variables: stall type, herd size, SCC, area, parity and morbidity per year. f) Somatic cell counts in bulk tank milk ($\times 10^3/m$). g) Adjusted by six variables: stall type, herd size, milk yield, area, parity and morbidity per year. * $P<0.05$.

occurred within 60 days after calving [1]; therefore, control of peripartum disease is thought to improve dairy productivity. In particular, dry period management is important,

because early postpartum diseases subsequently decrease the productivity and reproductive performance of dairy herds. Moreover, peripartum disease incidence and reproductive

performance after calving are influenced by management during the peripartum period [2, 4, 6]. A previous report showed that high disease incidence and reduced fertility in high-producing herds result from poor management rather than from biological agents [8]. Grummer *et al.* [7] reported that negative energy balance is problematic for late gestation cows; additionally, they also showed that a large reduction in energy balance around calving may cause periparturient health disorders in dairy cattle. Maizon *et al.* [14] reported that the days open in cows with diseases occurring in the first 45 days after calving was significantly extended compared with the reference group. Mulligan *et al.* [17] reviewed a prevention approach for production diseases in dairy cows and also indicated that nutritional management in late lactation is more effective for preventing production diseases. Therefore, these previous reports showed that prepartum management affects the incidence of production diseases during early lactation and that cows with diseases during the early lactation period have reduced milk production and reproductive performance. Thus, these previous reports supported our study result that dairy herds in Fukuoka, Southern Japan, with a high culling and death rate within 30 days after calving, had extended days open.

In summary, these data indicate that dairy herds with a high culling and death rate within 30 days after calving have lower reproductive performance in Fukuoka, Southern Japan. Therefore, this suggests that proper dairy herd management in Fukuoka during the dry period, which aims to prevent the increase of culling and death rate during early lactation, may maintain or improve reproductive performance. To our knowledge, the present study is the first study to use data from three organizations related to dairy herds in the whole of Fukuoka prefecture; nevertheless, this study was limited as it was a herd-level cross-sectional study that was carried out over the period of 1 year. Further studies at the individual cow level for a longer period, using the database created in this study, are needed in order to clarify the key management points for improving the production and reproductive performance of dairy herds in this area.

ACKNOWLEDGMENTS. We are grateful to the Livestock Improvement Association of Japan, Inc. and Fukuoka Prefecture Federation of Agricultural Mutual Relief Association and Fukuoka Prefecture Dairy Cooperative Associations for provision of data.

REFERENCES

1. Beudeau, F., Ducrocq, V., Fourichon, C. and Seegers, H. 1995. Effect of disease on length of productive life of French Holstein dairy cows assessed by survival analysis. *J. Dairy Sci.* **78**: 103–117. [Medline] [CrossRef]
2. Bertics, S. J., Grummer, R. R., Cadorniga-Valino, C. and Stoddard, E. E. 1992. Effect of prepartum dry matter intake on liver triglyceride concentration and early lactation. *J. Dairy Sci.* **75**: 1914–1922. [Medline] [CrossRef]
3. García-Ispuerto, I., López-Gatius, F., Santolaria, P., Yáñez, J. L., Nogareda, C. and López-Béjar, M. 2007. Factors affecting the fertility of high producing dairy herds in northeastern Spain. *Theriogenology* **67**: 632–638. [Medline] [CrossRef]
4. Gearhart, M. A., Curtis, C. R., Erb, H. N., Smith, R. D., Sniffen, C. J., Chase, L. E. and Cooper, M. D. 1990. Relationship of changes in condition score to cow health in Holsteins. *J. Dairy Sci.* **73**: 3132–3140. [Medline] [CrossRef]
5. Goff, J. P. and Horst, R. L. 1997. Physiological changes at parturition and their relationship to metabolic disorders. *J. Dairy Sci.* **80**: 1260–1268. [Medline] [CrossRef]
6. Grummer, R. R. 1995. Impact of changes in organic nutrient metabolism on feeding the transition dairy cow. *J. Anim. Sci.* **73**: 2820–2833. [Medline]
7. Grummer, R. R., Mashek, D. G. and Hayirli, A. 2004. Dry matter intake and energy balance in the transition period. *Vet. Clin. North Am. Food Anim. Pract.* **20**: 447–470. [Medline] [CrossRef]
8. Gröhn, Y. T. and Rajala-Schultz, P. J. 2000. Epidemiology of reproductive performance in dairy cows. *Anim. Reprod. Sci.* **60–61**: 605–614. [Medline] [CrossRef]
9. Gwazdauskas, F. C., Lineweaver, J. A. and McGilliard, M. L. 1983. Environmental and management factors affecting estrous activity in dairy cattle. *J. Dairy Sci.* **66**: 1510–1514. [Medline] [CrossRef]
10. Dohoo, I. R. and Martin, S. W. 1984. Disease, production and culling in Holstein-Friesian cows V. Survivorship. *Prev. Vet. Med.* **2**: 771–784. [CrossRef]
11. Koketsu, Y. 2002. The basics and application of the epidemiology: Take pig farming for example. *Journal of Veterinary Epidemiology* **6**: 1–10 (In Japanese). [CrossRef]
12. Kossaibati, M. A. and Esslemont, R. J. 1997. The costs of production diseases in dairy herds in England. *Vet. J.* **154**: 41–51. [Medline] [CrossRef]
13. LeBlanc, S. J., Lissemore, K. D., Kelton, D. F., Duffield, T. F. and Leslie, K. E. 2006. Major advances in disease prevention in dairy cattle. *J. Dairy Sci.* **89**: 1267–1279. [Medline] [CrossRef]
14. Maizon, D. O., Oltenacu, P. A., Gröhn, Y. T., Strawderman, R. L. and Emanuelson, U. 2004. Effects of diseases on reproductive performance in Swedish Red and White dairy cattle. *Prev. Vet. Med.* **66**: 113–126. [Medline] [CrossRef]
15. Correa, M. T., Erb, H. N. and Scarlett, J. M. 1993. Risk factors for downer cow syndrome. *J. Dairy Sci.* **76**: 3460–3463. [Medline] [CrossRef]
16. Ministry of Agriculture Forestry and Fisheries. 2013. The 88th Statistical Yearbook of Ministry of Agriculture, Forestry and Fisheries (2012–2013). http://www.maff.go.jp/e/tokei/kikaku/nenji_e/88nenji/ (accessed 30 January 2015).
17. Mulligan, F. J., O'Grady, L., Rice, D. A. and Doherty, M. L. 2006. A herd health approach to dairy cow nutrition and production diseases of the transition cow. *Anim. Reprod. Sci.* **96**: 331–353. [Medline] [CrossRef]
18. Nakada, K. 2013. Shall we start epidemiological study using production data in Japanese dairy farms? *Journal of Veterinary Epidemiology* **17**: 5–9 (In Japanese with English abstract). [CrossRef]
19. Pinedo, P. J., De Vries, A. and Webb, D. W. 2010. Dynamics of culling risk with disposal codes reported by Dairy Herd Improvement dairy herds. *J. Dairy Sci.* **93**: 2250–2261. [Medline] [CrossRef]
20. Reneau, J. K. and Kinsel, M. L. 2001. Record systems and herd monitoring in production-oriented health management programs in food-producing animals. pp. 107–146. *In: Herd Health: Food Animal Production Medicine*, 3rd ed. (Radostits, O. M. ed.), W. B. Saunders, Philadelphia.
21. Rapnicki, P. and Overton, M. W. 2014. Disease Records for Impactful Decisions During the Vital 90TM Days. https://ecommons.cornell.edu/bitstream/handle/1813/37967/CNC2014_2_Rapnicki.pdf (accessed 1 November 2015).