Effects of Housing type × Feeding System on Milk Yield of Holstein Cows

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ABSTRACT: We examined the effects of housing type × feeding system on Holstein milk yield, using 305-day milk yield records for 382,269 cows in Japan calving between 2008 and 2012. Milk yield records were analyzed in first-, second-, and third-lactation subsets. There were three barn-type traits (tie-stall [TS], free-stall [FS], and grazing [GZ]). We used a trivariate animal model for multiple-trait analyses. Two different feeding systems (separate feeding of pasture plus concentrate, SF; total mixed ration, TMR) and different numbers of management groups (MGs) per farm (1, 2, or >2) were evaluated. For the effect of housing × feeding system × MG number, higher milk yields were estimated for TS/TMR/2MG (+663, +911, and +968 kg for first, second, and third lactations, respectively) and FS/TMR/3MG (+518, +783, and +757 kg, respectively) than with TS/SF/1MG. The GZ/SF/1MG estimates (–530, –525, and –490 kg, respectively) were the lowest.

Keywords: Holstein; housing type; feeding system

Introduction

Dairy cows in Japan have traditionally been kept in tie-stall (TS) barns, and herds have been small. Generally the feeding systems used are separate feeding (SF) of dried pasture plus concentrates, or feeding of total mixed ration (TMRs) in which the dried pasture and concentrates are mixed. In recent years in Japan, there has been a trend toward housing dairy cows in free-stall barns (FS) instead of TS ones to expand herd size for increased profits and improve labor efficiency in dairy operations. With this change, many cows are being fed TMRs in management groups (MG). Feeding a TMR allows producers to incorporate all the required ingredients into a single ration to meet their cows' nutritional requirements and optimize herd milk production (Endres and Espejo (2010)). Hovinen et al. (2009) reported that differences among types of housings affected milk yield. Bargo et al. (2002) reported that TMR feeding systems gave higher milk production than SF grazing outside on pasture conditions (GZ). Caccamo et al. (2010) reported that the shapes of the lactation curve and milk yield differ between SF- and TMR-fed cows. Because both housing type and feeding system affect milk yield, a study of the interactions between housing type and feeding system would be important to the dairy industry. Our objective was to compare the effects of housing type × feeding system on milk yield in Holsteins in Japan.

Materials and Methods

Data. Records of milk yields in the first three lactations of Holstein cows that had calved between 2008 and 2012 were provided by the Hokkaido Dairy Milk Recording and Testing Association (Sapporo, Japan). The records were collected through the Dairy Herd Improvement Program. We estimated the 305-day milk yield (MY) by using a multiple-trait prediction (Schaeffer and Jamrozik (1996)) according to Wilmink's function (Wilmink (1987)). Lactation records for which there were fewer than eight test-day yields during the lactation period were eliminated. Records of the housing management system, the feeding system, and the number of MGs (e.g. grouped by lactation stage) were obtained from the dairy farm operators. The data included three types of housing (TS, FS, and GZ) and two types of feeding system (SF and TMR). GZ meant that cows were managed mainly by grazing outside on pasture except for the winter season. Combining TMR with GZ (GZ/TMR) meant that the cows received partial TMRs, because the pasture grazed by the cows was not part of the TMR. If more than one MG existed, the number of MGs in the herd was classified as 1, 2, or 3, where 3 represented 3 or more. If the housing type, feeding system, or number of MGs changed in the period from 2008 to 2012, the records for that herd were removed from the study. Records for those farms with combined housing types or feeding systems, or with MGs constructed with fewer than 10 herds, were also deleted. Records of MY were assigned separately as three subsets, for cows in their first, second, and third lactations. Pedigree records of 648,244 animals obtained from the Holstein Cattle Association of Japan (Tokyo, Japan) were traced back three generations. The total number of records was 696,583 from 382,269 cows.

Model. Genetic parameters and best linear unbiased estimations (BLUEs) were estimated from a trivariate animal model by considering the genetic covariance among records for TS, FS, and GZ. The following linear models were applied to MY for each subset:

$$Y_{ijklmno} = HY_i + M_j + A_k + DB_l \times FDS_m \times MG_n + u_{lo} + e_{ijklmno},$$

where $Y_{ijklmno}$ is MY; HY_i is the fixed effect of herd year i; M_j is month of calving j (12 calendar months); A_k is the fixed effect of age group at calving k (18–20, 21–22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, and 35 months for first lactation; ≤35, 36–37, 38–39, 40–41, 42–43, 44–45, 46–47, and 48–49 months for second lactation; and ≤45, 46–50, 51–55, 56–60, 61–65, and 66–83 months for third lactation); $DB_l \times FDS_m \times MG_n$ is the interaction of housing l (TS, FS, or GZ) × feeding system m (SF or TMR) × number of MGs n (1, 2, or 3); u_{lo} is housing l × the random additive genetic effect of animal o; and $e_{ijklmno}$ is random residuals. The variances were defined as

$$\mathrm{var}\begin{bmatrix} u \\ e \end{bmatrix} = \begin{bmatrix} G \otimes A & 0 \\ 0 & R \otimes I \end{bmatrix},$$

where G is a 3 × 3 covariance matrix for additive genetics; R is a 3 × 3 diagonal matrix of the residual variance corresponding to each trait (TS, FS, or GZ); A is the matrix of additive genetics among animals; I is the identity matrix for records; and $\otimes$ is the Kronecker product.

The GIBBS3F90 program (Misztal et al. (2002)) was used for Gibbs sampling to estimate the genetic parameters of the linear models. A flat prior was used for fixed effects, and an inverted Wishart distribution was used as the prior on the random effects. For each analysis, 100,000 samples after a burn-in of 50,000 iterations were used to calculate the posterior means and standard deviations of the covariance components. Convergence was determined from a visual inspection of the plotting of Gibbs samples.

Solutions for fixed effects of housing × feeding system × number of MGs were obtained iteratively by using a preconditioned conjugate gradient algorithm with iteration on data (Tsuruta et al. (2001)) in a program for Japanese national evaluation (developed by the National Livestock Breeding Center).

Results and Discussion

Mean MY ranged from 6656 to 11,075 kg in the first three lactations (Table 1). The greatest numbers of records and herds were observed in TS/SF/1. The total number of first-lactation records was 125,754 in TS from 2071 herds; 147,364 in FS from 825 herds; and 6171 in GZ from 100 herds. About 45%, 53%, and 2% of cows and 69%, 28%, and 3% of herds were being managed in TS, FS, and GZ, respectively. We found that 73% of TS cows (79% of herds) were given SF, 87% of FS cows (83% of herds) were given TMRs, and 59% of GZ cows (71% of herds) were given additional SF. Many TS and GZ herds were managed in 1-MG systems, but in the case of FS cows there were almost the same numbers (more than 40,000 in each case) in 1-, 2-, and 3-MG systems. The average number of cows in the first three lactations in a herd (herd size) was 35.3 for TS, 92.0 for FS, and 35.5 for GZ. FS/SF/3 and FS/TMR/3 had the greatest herd size (135.6 and 157.4, respectively).

Table 1. Means (s.d.) of 305-day milk yields with different housing types, feeding systems, and numbers of management groups.

Housing / feeding system* / MG†	Records (herds)	305-day milk yield (kg)		
		First lactation	Second lactation	Third lactation
TS/SF/1	85111 (1517)	7735 (1556)	8838 (1822)	9178 (1902)
TS/SF/2	3882 (74)	7706 (1401)	8780 (1664)	9187 (1822)
TS/SF/3	2815 (48)	8256 (1534)	9402 (1836)	9684 (1876)
TS/TMR/1	29632 (381)	8562 (1615)	9893 (1978)	10257 (2084)
TS/TMR/2	2868 (35)	9002 (1592)	10604 (1856)	11075 (1996)
TS/TMR/3	1446 (16)	8850 (1540)	10179 (1790)	10597 (1797)
FS/SF/1	7235 (79)	7616 (1525)	8775 (1836)	9160 (1912)
FS/SF/2	4438 (34)	8116 (1584)	9400 (1908)	9767 (2042)
FS/SF/3	7179 (24)	8534 (1911)	9784 (2223)	9959 (2267)
FS/TMR/1	42092 (307)	8223 (1625)	9532 (1963)	9824 (2081)
FS/TMR/2	42248 (250)	8246 (1559)	9606 (1890)	9914 (2022)
FS/TMR/3	44172 (131)	8790 (1679)	10392 (2006)	10720 (2165)
GZ/SF/1	3626 (71)	6656 (1241)	7751 (1462)	8180 (1549)
GZ/TMR/1	2545 (29)	7207 (1297)	8512 (1571)	8898 (1714)

*Housing types: TS = tie stall; FS = free stall or free barn; GZ = grazing outside on pasture; Feeding systems: SF = separate feeding; TMR = total mixed ration

†Number of management groups on a dairy farm (1, 2, or 3, where 3 = 3 or more).

The BLUE values for MY in cows were higher in TS and FS than in GZ in all three lactation periods (Table 2). BLUEs were higher in cows in TS/TMR (ranging from +417 to +968 kg) than in TS/SF (ranging from –44 to +278 kg). BLUEs in cows in FS/TMR/3 (ranging from +518 to +783 kg) were higher than for other combinations with FS (ranging from –92 to +454 kg). The differences between SF and TMR in combinations of first lactation ranged from +305 to +690 kg in TS and from +30 to +287 kg in FS; the difference in the case of GZ was +258 kg. The differences in BLUE between SF and TMR were highest in TS. In the second lactation the differences between SF and TMR ranged from +376 to +955 kg in TS and from +82 to +361 kg in FS; for GZ the difference was +371 kg. In the third lactation the differences between SF and TMR ranged from +448 to +982 kg in TS and from +66 to +391 kg in FS; for GZ the difference was +356 kg. TMR was more effective in increasing MY in later-parity cows, and MY in later-parity cows was more susceptible to differences in the feeding system than was MY in first-lactation cows.

Table 2. Best linear unbiased estimations (s.e.) of milk yield for housing × feeding system × number of management groups.

Housing / feeding system* / MG†	Milk yield (kg) in first lactation	Milk yield (kg) in second lactation	Milk yield (kg) in third lactation
TS/SF/1	0(4)	0(4)	0(5)
TS/SF/2	–27(17)	–44(19)	–14(23)
TS/SF/3	241(22)	278(26)	245(30)
TS/TMR/1	417(7)	525(9)	534(11)
TS/TMR/2	663(25)	911(31)	968(39)
TS/TMR/3	546(33)	654(41)	693(50)
FS/SF/1	– 92(15)	– 49(19)	– 23(22)
FS/SF/2	196(20)	288(26)	287(32)
FS/SF/3	368(18)	454(25)	366(31)
FS/TMR/1	195(7)	312(9)	296(11)
FS/TMR/2	226(6)	370(9)	353(11)
FS/TMR/3	518(7)	783(9)	757(12)
GZ/SF/1	–530(15)	–525(19)	–490(22)
GZ/TMR/1	–272(19)	–154(25)	–134(31)

*Housing types: TS = tie stall; FS = free stall or free barn; GZ = grazing outside on pasture. Feeding systems: SF = separate feeding; TMR = total mixed ration

†Number of management groups on a dairy farm (1, 2, or 3, where 3 = 3 or more).

The use of 3 MGs appeared superior in TS/SF, and 2 MGs was superior in TS/TMR. When TS/TMR herds had more than 1 MG, different diets — e.g. supplements in conjunction with the TMR (Soriano et al. (2001)), or different TMRs (e.g. 74% total digestible nitrogen (TDN) and 71% TDN) — would likely have been fed. Although the use of 3 MGs gave higher yields than 1 or 2 MGs in the case of FS/TMR, only a small differences existed between 1 and 2 MGs. The decision to group in 1 to 2 MGs usually depends on the stage of lactation in Japan, but such groupings may make little difference to MY in FS.

Conclusion

We estimated that there were high milk yields with TMR/2MG in TS and TMR/3MG in FS. The lowest estimates were obtained with GZ/SF/1MG. The BLUEs of MY were higher with TMR than with SF, and the difference between the effects of SF and TMR was greatest in TS. TMR was more susceptible to differences in the feeding system in later-parity cows than in first-lactation cows. Applying this information is likely to improve the profitability of dairy farms in Japan.

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