THE TRENDS OF VARIATION IN SOME MEASURES OF LACTATION CURVES AMONG LACTATIONS AND CALVING SEASONS IN DAIRY COWS

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Introduction

It has been known that the general shape of a lactation curve is affected by the age of cows[8~10,16~18], seasons[8~10,16], feeding system[18] and other environmental factors[17].

The shape of lactation curves can be set depending on the initial milk yield or peak yield, and its persistency. Many models to measure a persistency, have been proposed[1~4,6~9,11,14].

The highest persistency was attained by cows calving in the winter months and summer calvers were the poorest, in northern Europe[9,18]. However, when cows were kept indoors all the year round and fed grass silage with a concentrate supplement, the shape of the curve was substantially the same for all cows irrespective of their calving seasons[18]. The seasonal variation in shape of lactation curves that was observed in the traditionally managed herds, could be attributed largely to differences in the prevailing conditions of food supply in the different months of the year. The conditions of food supply may be changed among different latitudes and climates.

Understanding the general trend of variations in shape of lactation curves,

and their contributory factors, may be important for farmers to attain the best management of dairy cattle. The measurements of the possible variation are indispensable to compare the breeding values of production traits among the cows kept in different conditions. The objectives of this study were to investigate the general trend of variation in several measures related to the lactation curve, with a parity and calving seasons.

Materials and Methods

The daily milking records of Holstein breed cows were obtained from Niikappu National Livestock Breeding Station, Shizunai, Hokkaido. The data included in this investigation were the records of the first to third lactations whose calving date was after January 1st, 1960, and whose milking records was longer than 180 days before July 31st, 1977. The total number of data was 704 lactation records, which included the numbers within sub-groups presented in Table 1.

TABLE 1. The number of lactation records included in this investigation

Parity (lactation number)	Calving seasons (calender months of calving)						Sub-total
	January February	March April	May June	July August	September October	November December	
1	51	70	46	53	44	58	332
2	34	60	30	40	30	24	218
3	19	42	26	29	26	22	164
Sub-total	104	172	102	122	100	104	704

The daily milking records were fitted to the exponential function described by WOOD (1967)[14], as follows:

$$Y_n = A \cdot n^B \cdot e^{-C \cdot n} \qquad (1)$$

where Y_n is the daily milk yield in the n-th day after the beginning of milking, and A, B and C are constants. The daily milking records were fitted to the above equation to the 180-th day, according to SHIMIZU and UMROD (1976)[12]. From the above equation (1), the peak milk yield occurs where n is B/C (this stage was symbolized as T_{max}) and its yield is estimated as $A \cdot (B/C)^B \cdot e^{-B}$ (symbolized as MY_{max}). The reflection point of the curve is estimated as $T_{ref} = B/C + \sqrt{B}/C$. WOOD (1967)[14] also defined the measure of persistency as $C^{-(B+1)}$ or $-(B+1) \cdot \ln C$. In this study, the persistency was measured as a later definition (as S-Wood $= -(B+1) \cdot \ln C$). Three other

measures of persistency were measured too, as follows:

$$\text{S-LuPe} = 4\frac{MY_2}{MY_1} + 3\frac{MY_3}{MY_2} + 2\frac{MY_4}{MY_3} + \frac{MY_5}{MY_4} \quad (2)$$

$$\text{S-JoHa} = \frac{MY_{180} - MY_{90}}{MY_{90}} \times 100 \quad (3)$$

$$\text{S-Maha} = \frac{MY_{180} - MY_{70}}{MY_{70}} \times 100 \quad (4)$$

These three models are the modefied ones of LUDWICK and PETERSEN (1943)[7], JOHANSSON and HANSSON (1940)[6], and MAHADEVAN (1951)[9], respectively. In the above equations, MY_1, MY_2, MY_3, MY_4, MY_5, are 2 nd, 3 rd, 4 th, 5 th and 6 th total milk yield for 30 days after the beginning of lactation. And MY_{180}, MY_{90}, and MY_{70} are total milk yield for the first 180 days, 90 days, and 70 days of milking, respectively.

Statistical analysis was conducted by the least squares analysis methods according to HARVEY (1960)[5]. Two factors were assumed, which were: three levels of parity (the first, second and third lactations); and six levels of calving seasons that grouped together in two consecutive calender months. The mathematical models for the two-way classification with interaction is as follows:

$$Y_{ijk} = m + a_i + b_j + (a \cdot b)_{ij} + e_{ijk} \quad (5)$$

where Y_{ijk} is the k-th measurement in the j-th calving season group and i-th parity group, m is the overall mean with equal subclass numbers, a_i is the effect of the i-th parity class, b_j is the j-th calving season subclass after the average effects of lactation and calving season have been removed and e_{ijk} is random errors. The effects of parity and calving season are assumed to be fixed. In statistical analysis, atypical lactation curves which have negative B or negative C estimates are excluded.

Results

Overall means and the effects of lactation and calving season are presented in Table 2, as the constant estimates of the least squares analysis. The significances of the effects are also given in the table. The general trend of the variation in eight measures of lactation curve is shown in Fig. 1 with parity and calving season, which are shown as the per cent of the effects to the corresponding means in Table 2. The effects of parity and calving season were statistically significant in all measures. However, there was no evidence of any interaction between the parity and the calving season.

TABLE 2. The effects of parity and calving seasons on measures of lactation curves, that are given as the least squares constants

Items	MY_{180} (kg)	MY_{max} (kg)	T_{max} (days)	T_{ref} (days)	S-Wood	S-LuPe	S-JoHa (%)	S-Maha (%)
Overall means	4115.0	27.60	22.0	73.9	6.05	9.02	77.7	122.8
Parity								
1st lactation	−434.0	−3.60	3.93	12.2	0.14	0.08	3.1	4.2
2nd lactation	151.0	1.41	−2.17	−6.8	−0.07	−0.07	−1.4	−1.4
3rd lactation	283.0	2.19	−1.76	−5.4	−0.07	−0.01	−1.4	−1.4
Significant difference	**	**	**	**	**	**	**	**
Calving seasons								
1. Jan.-Feb.	216.0	0.81	2.11	9.6	0.11	0.18	4.1	5.7
2. Mar.-Apr.	56.0	0.77	2.72	−2.6	−0.04	−0.10	−3.1	−2.7
3. May-Jun.	77.0	0.57	−4.30	−11.9	−0.17	−0.12	−3.3	−5.5
4. Jul.-Aug.	−136.0	−0.97	2.11	3.1	0.03	−0.01	0.2	0.5
5. Sep.-Oct.	−41.0	−0.37	−0.05	−0.8	−0.02	−0.03	−0.1	−0.3
6. Nov.-Dec.	−19.0	−0.81	−2.59	2.6	0.09	0.08	2.3	2.3
Significant difference	*	**	**	**	**	**	**	**

* $P<0.05$, ** $P<0.01$

The milk yield for the first 180 days (MY_{180}) and the maximum daily milk yield (MY_{max}) tended to increase with increasing numbers of lactation. The number of days when the maximum daily milk yield reached (T_{max}) and the days when the reflection of lactation curve occurred (T_{ref}) were later for the first lactation than for the second and third lactations. All four measures of persistency of lactation (S-Wood, S-LuPe, S-JoHa and S-Maha) show a similar trend of variation among lactation, and are also as same as T_{max} and T_{ref}. The persistency of the first lactation was larger than the other two later lactations.

MY_{180} was the highest for the cows calving in winter (January and February), and consistently decreased as the calving season dew near summer when MY_{180} was the lowest. The cows calved in January through June had higher MY_{max} than the cows calved in other months of the year. The lactation curves started in May, June, November, and December, reached the maximum daily milk yield earlier than the lactation curve started in January through April, and Jully to August. T_{ref} and four measures of persistency show the same trend of variation among calving seasons. The

higher persistencies were attained by the cows calving in winter (November through February), while the lower values were attributable to the cows calving in spring and early summer (March through June).

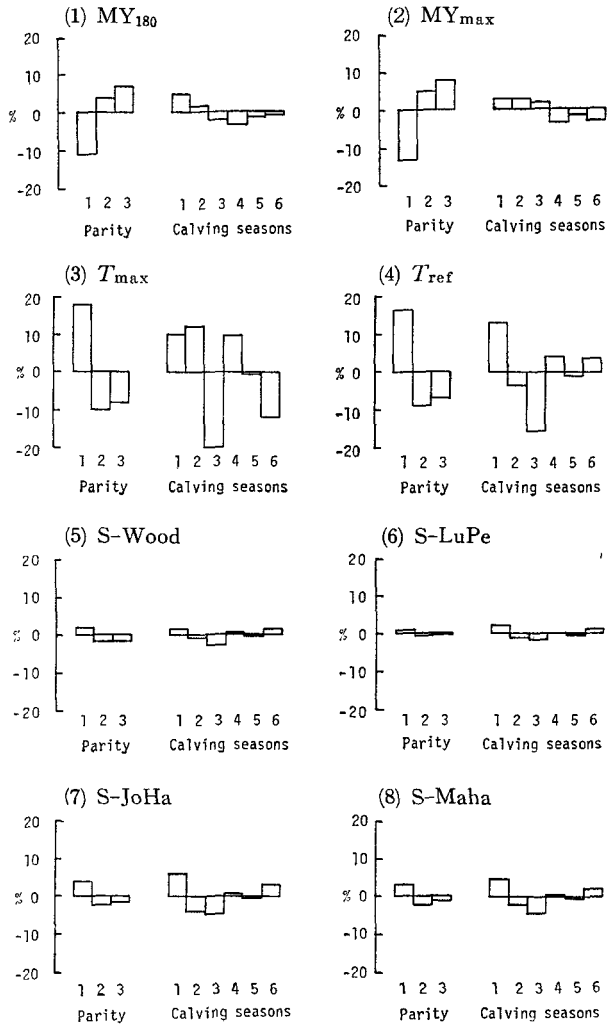

Fig. 1. The effects of parity and calving season on the measures of lactation curve, that are presented in per cent (%) of each effect to overall means.
Parity: 1=1st lactation, 2=2nd lactation and 3=3rd lactation. Calving season: 1=January and February, 2=March and April, 3=May and June, 4=July and August, 5=September and October, and 6=November and December.

Discussion

The results obtained in this study, show that a parity and calving season significantly affected a milk yield and all measures of the lactation curve. The total milk yield for the first 180 days (MY_{180}) and the maximum daily milk yield (MY_{max}) were lower for the first lactation than for the second and third lactations, while T_{max}, T_{ref} and four persistencies of milk yield (S-Wood, S-LuPe, S-JoHa and S-Maha) showed the reverse trend of the milk yields among lactations. The relationships of the milk yield with T_{max}, T_{ref} and persistencies showed apparent negative correlation among parities. The fact that persistencies considerably vary with lactation, has been shown, irrespective of the models[8,9,15,18]. It has been also observed that a persistency dropped from the first to the second lactation and did not show much variation between second and later calvers[9,15]. The experimental results obtained in this study agreed well with those reported results.

The results obtained from the record of cows kept in England, Wales[15] and Scotland[9] persented the significant variation in persistency with the calving season, and showed that the highest persistency was attained by cows calving in the winter months, while the lowest values were attributable to summer calvers. MADSEN (1975)[8] compared some measures of persistency models. In his study, a measure of the absolute decrease of milk yield during the lactation was significantly affected by the month of calving, while other persistency models (ratios of total to part yield for various periods, and Wood's model) showed no significant variation according to the month. WOOD (1972)[18] investigated the lactation record obtained from the cows which were kept indoors all year round and fed grass silage with a concentrate supplement. And, the seasonal variation in persistency and peak week were compared with that from cows traditionally managed. The results showed that the seasonal variation was considerably less evident in the indoor herds than in the traditonally managed ones. The feeding of grass conserved in a rapidly growing state in early summer was an important contributory cause to seasonal variation in milk yield. The general trend of variation in persistency with the calving month closely agreed with each of the four models in the Niikappu herd. This trend is in good agreement with the results of the cows in northern Europe, though lower persistency is attributable to cows calved in spring in the Niikappu herd.

There is no consistent relationship between the maximum daily milk yield and a persistency among calving months. This fact may be explained by the fact that there is a lag in the time when the good condition of

feeding contributes to each of the two measures separetely. A total milk yield positively correlated to the maximum daily milk yield and the persistency in some studies[8,9]. The highest total milk production (MY_{180}) that was attained by the cows calved in January and February is owing to the highest maximum daily milk yield and persistency. The cows calved in early summer (May to June) have high maximum milk yield but the lowest persistency. These cows produce less total milk for a longer period. The maximum daily milk yields of the cows calved in early winter are less, but the values of persistency are second to the values of the cows calved in January and February. Their total milk yield is near average.

In a practical importance of management, a feeding after the peak yield must be improved for the cows calved in spring and early summer, and good feeding for the first month is necessary for the cows calved in summer to early winter, so that a high milk production may be attained.

The total milk production may be defined as a function of the initial peak yield and its persistency. The breeders may show much interest in the genetic variation of a persistency. What model of persistency is most efficient as a selection criterion to improve the total milk production depends on its genetical property. The investigation related to this problem is presented in the following study.

Summary

In this study, a general trend of variation in the measures of lactation curves with a parity and the season of calving was investigated with a total of 704 lactation records of Holstein breed cows which were collected in Niikappu National Livestock Breeding Station at Shizunai, Hokkaido.

The effects of parity and calving season were significant on all measures of the lactation curve. Total milk yield for the first 180 days and the maximum daily milk yield tended to increase according to the increasing number of lactation. The days which reached the maximum daily milk yield and the reflection point of the lactation curve (fitted to WOOD's model) were later for the first lactation than for the second and third. The persistency of the first lactation was higher than the other lactations. The higher persistencies were attained by the cows calving in winter, while the lower values were attributable to cows in spring and early summer.

The results of this study were computed at the Hokkaido University Computing Center.

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