

MILK YIELD AND ITS REPEATABILITY IN JAPANESE BLACK COWS

K. Shimada,^a Y. Izaike, O. Suzuki, T. Oishi^b
and M. Kosugiyama

Chugoku National Agricultural Experiment Station, Oda-shi, 694, Japan

Summary

Daily milk yield estimates were obtained on 74 lactations of 35 Japanese Black cows on weeks 1 to 9, 11, 13, 17, 21 and 26 postpartum using the weigh-suckle-weigh method. The data obtained were analyzed by least-squares procedures according to the models including the following effects; dam, lactation number, season of calving, week of experiment and partial regressions on the lactation number.

The overall mean and standard error for daily milk yield was 4.55 ± 0.04 kg. The milk yield declined essentially linearly throughout the experimental period. The main effects of lactation number, season of calving and week of experiment were highly significant. Differences in daily milk yield among cows were significant, and the repeatability was estimated as 0.60 ± 0.06 . The overall means (kg) and repeatabilities of cumulative milk yield for 1, 4, 9, 13, 17, 21 and 26 weeks postpartum were 41.0, 0.08; 166.0, 0.40; 361.0, 0.61; 503.0, 0.66; 632.0, 0.67; 749.0, 0.65 and 884.0, 0.58, respectively.

The means of calf weight at birth and 26 weeks weight for different lactations ranged from 25.5 to 33.6 kg and 145.6 to 185.4 kg, respectively. Calf daily gains between experiment weeks were low in earlier stages of lactation.

(Key Words: Milk Yield, Lactation Curve, Repeatability, Calf Growth, Japanese Black Cows)

Introduction

It is well established that the milk yield of beef cow has a large effect on calf growth (Somerville et al., 1983; Clutter and Nielsen, 1987). McMorris et al. (1986) reported in their economic study that increased milk yield had a positive linear effect on the gross margin of the integrated production system. Recently in Japan, the importance of milk yield has been recognized in Japanese Black cows. However, there is a lack of detailed knowledge on milking ability of this breed.

The objectives of this study were to describe the lactation curve of Japanese Black cows and to estimate repeatability of milk yield. Additionally, the relationship between milk yield and calf growth was determined.

Materials and Methods

Animal and management

Thirty-five Japanese Black cows derived from

the experimental herd maintained at Chugoku National Agricultural Experiment Station (latitude $35^{\circ}10'N$, longitude $132^{\circ}30'E$), were involved in the study; data were obtained from 74 lactations. Of these, 11 were first lactation, and the others were second to ninth. The experiment was carried out between 1982 and 1986. Cows were allowed to graze from April to November until approximately two weeks before calving. After parturition, cows and calves were maintained in pens. Cows were fed 20 kg of silage, 2 kg of hay and 2 kg of concentrate per day. Calves were fed hay *ad libitum* and a pelleted creep ration of not more than 2 kg per day.

Milk production and live weight

Daily milk yield estimates were obtained during weeks 1 to 9, 11, 13, 17, 21 and 26 postpartum for first to third lactations, and in weeks 1 to 9, 13 and 26 for subsequent lactations using the weigh-suckle-weigh method. In order to start all cows under equal conditions, cows and calves were separated at 9.00 h (13.00 h for 1-2 week postpartum) on the first day, and allowed to suckle at 16.00 h. The following two consecutive days, calves were weighed to the nearest 100 g and allowed to suckle at 9.00 h and at 16.00 h. The four calf weight increments were summed and

^a Address reprint requests to K. Shimada, Chugoku National Agricultural Experiment Station, Kawaicho, Oda-shi, Shimane-ken 694, Japan

^b Present address: National Institute of Animal Industry, Tsukuba Norindanchi, 305, Japan

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divided by two for the estimate of daily milk yield.

Cow and calf were weighed within 24 h post-partum and at the beginning of each milk recording week. Calf weight was calculated as the mean of weights before and after suckling.

Statistical methods

In order to calculate cumulative milk yield for each cow, an equation developed by Wood (1969) was fitted to the estimates of daily milk yield.

The data obtained were analyzed by least-squares procedures (Harvey, 1977). The daily milk yield was analyzed according to the following model:

$$Y_{ijkl} = \mu + L_i + S_j + W_k + e_{ijkl} \quad (I)$$

where

- Y_{ijkl} = daily milk yield
 μ = overall mean
 L_i = fixed effect of the i th lactation
 S_j = fixed effect of the j th season of calving
 W_k = fixed effect of the k th week of the experiment
 e_{ijkl} = the residual error term

In order to estimate the variance component of dam, the following two mixed models were adopted:

$$Y_{ijkl} = \mu + d_i + S_j + W_k + b_1 L^1 + b_2 L^2 + b_3 L^3 + e_{ijkl} \quad (II)$$

where

- Y_{ijkl} = daily milk yield
 μ = overall mean
 d_i = random effect of the i th dam
 S_j = fixed effect of the j th season of calving
 W_k = fixed effect of the k th week of experiment

b_1, b_2 and b_3 = linear, quadratic and cubic partial regression coefficients on the lactation number (L.)

e_{ijkl} = the residual error term

and

$$Y_{ij} = \mu + d_i + b_1 L^1 + b_2 L^2 + b_3 L^3 + e_{ij} \quad (III)$$

where

Y_{ij} = cumulative milk yield

The other elements were as defined for Model II.

Repeatability estimate was obtained as follows:

$$r = \hat{\sigma}_d^2 / (\hat{\sigma}_d^2 + \hat{\sigma}_e^2)$$

where

r = repeatability estimates of daily or cumulative milk yield

$\hat{\sigma}_d^2$ = variance component of dam

$\hat{\sigma}_e^2$ = the residual error term

The standard error of repeatability was estimated according to Swiger et al. (1964).

Results

Cow live weight

The average live weights and standard deviations of cows during lactation were 367 ± 34 , 402 ± 44 , 433 ± 44 and 458 ± 50 kg for first, second, third and fourth to ninth lactations, respectively. For third lactations only, live weight decreased slowly throughout the lactation from 456 ± 49 kg at calving to 419 ± 44 kg at 26 weeks; for other lactations, weight generally was maintained.

Daily milk yield

The least-squares analysis of variance (Model I), and least-squares means and standard errors for daily milk yield are presented in table 1 and 2, respectively. The overall mean and standard error for daily milk yield was 4.55 ± 0.04 kg. The main effects of lactation number, season of calving and week of experiment were highly significant. Heifers (first lactation) and cows in eighth and ninth lactations gave significantly less milk than cows in second to seventh lactations, and spring-calving cows produced more milk than cows calving in other seasons.

Daily milk yield changes for different lactations are presented in figure 1. The milk yield of cows in these five lactation groups (first, second, third to fourth, fifth to seventh and eighth to ninth) declined essentially linearly, and the first and eighth to ninth lactations produced consistently less milk throughout the experiment.

Differences in daily milk yield among cows were significant, and the repeatability was estimated as 0.60 ± 0.06 from the Model II analysis

TABLE 1. ANALYSIS OF VARIANCE FOR DAILY MILK YIELD

Source	d.f.	Mean squares (kg)
Lactation	8	34.8***
Season of calving	3	42.1***
Experiment week	13	25.4***
Error	852	0.8

*** $P < 0.001$.

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TABLE 2. LEAST SQUARES MEANS AND STANDARD ERRORS FOR DAILY MILK YIELD (KG)

Effect	No.	Mean	S.E.
Overall mean	877	4.55	0.04
Lactation			
1	149	3.62 ^e	0.07
2	247	4.76 ^c	0.06
3	144	4.93 ^{bc}	0.08
4	127	4.99 ^{abc}	0.08
5	80	5.25 ^a	0.10
6	32	5.16 ^{ab}	0.16
7	37	5.06 ^{abc}	0.15
8	42	4.21 ^d	0.14
9	19	3.00 ^f	0.21
Season of calving			
Spring (Mar. - May)	209	5.15 ^a	0.08
Summer (Jun. - Aug.)	266	4.60 ^b	0.06
Autumn (Sep. - Nov.)	214	4.03 ^c	0.07
Winter (Dec. - Feb.)	188	4.44 ^b	0.08

a,b,c,d,e,f Means with different superscripts within main effects differ significantly (P < 0.05).

of variance (table 3). Linear, quadratic and cubic partial regression coefficients were 1.8632, -0.3549 and 0.0175, respectively. These values were different from zero (P < 0.001).

From Model III analysis of variance, overall means and standard errors of cumulative milk yield from parturition to 1, 4, 9, 13, 17, 21 and 26 weeks were 41 ± 2, 166 ± 7, 361 ± 15, 503 ± 21, 632 ± 27, 749 ± 32 and 884 ± 40 kg, respectively. Differences among cows were highly significant except first week. Repeatabilities for cumulative milk yield for each week are presented in table 3. As these estimates increased from 0.08 in 1 week to a maximum estimate 0.67 in 17 weeks, those of standard errors decreased from 0.17 to 0.09. Afterwards repeatability estimates decreased slightly. Quadratic partial regression coefficients in 4 to 26 weeks and cubic ones in 9 to 26 weeks were significant.

Calf growth

Least-squares means of calf birth weight for different lactation groups were 25.5 ± 1.3, 31.2 ± 1.0, 32.7 ± 0.9, 33.6 ± 1.2 and 33.6 ± 1.9 kg.

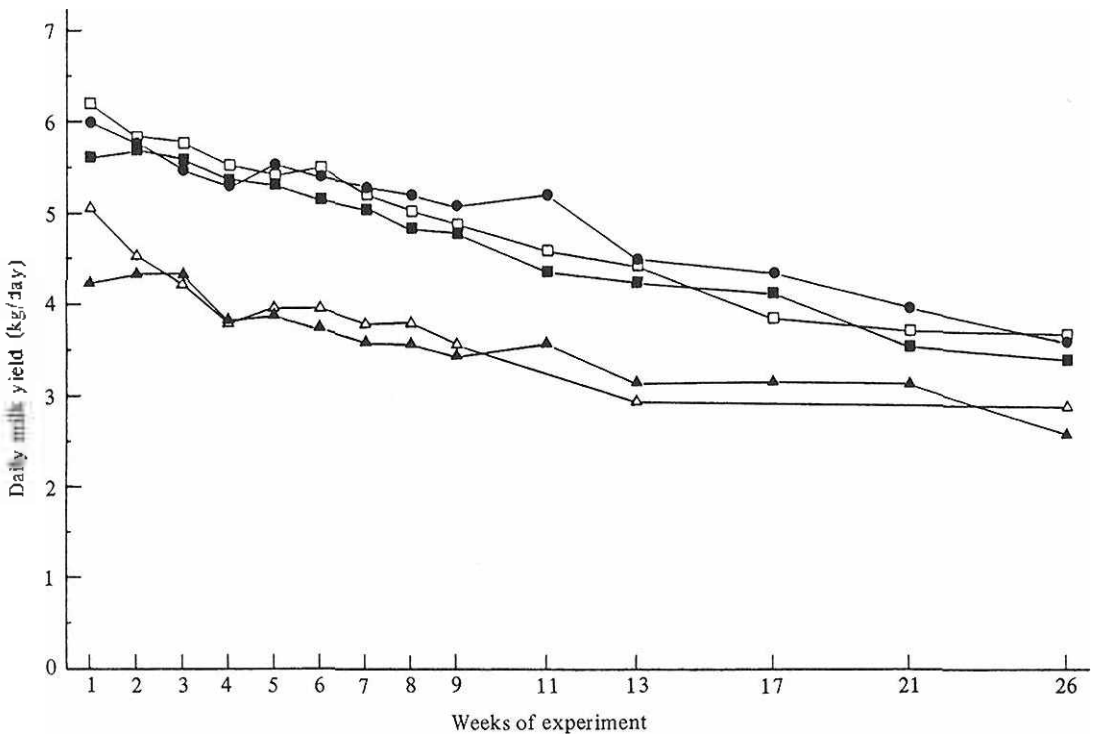


Figure 1. Daily milk yield for different lactations. ▲, 1st lactation; ■, 2nd lactation; ●, 3rd and 4th lactations; □, 5th to 7th lactations; △, 8th and 9th lactations.

TABLE 3. CAUSAL VARIANCE COMPONENTS, REPEATABILITY ESTIMATES AND STANDARD ERRORS

Variance components	Daily milk yield	Cumulative milk yield (Weeks)						
		1	4	9	13	17	21	26
Dam	0.53	8	370	2283	4728	7744	11198	16123
Residual	0.35	99	560	1485	2476	3865	6124	11431
Repeatability	0.60	0.08	0.40	0.61	0.66	0.67	0.65	0.58
Standard error	0.06	0.17	0.14	0.11	0.09	0.09	0.10	0.11

and those of 26 weeks weight were 145.6 ± 5.0 , 178.3 ± 4.0 , 176.0 ± 3.8 , 185.4 ± 5.2 and 183.3 ± 8.5 kg, respectively. The means of calf birth weight in spring, summer, autumn and winter were 32.0 ± 1.2 , 32.6 ± 1.0 , 29.7 ± 1.1 and 31.0 ± 1.1 kg, respectively.

Calf daily gains adjusted to a male calf basis between experiment weeks are shown in figure 2. At the start of the experiment, calf daily gains were higher than next several weeks except the

eighth to ninth lactation group. Minimum daily gains were recorded from 1 to 6 weeks postpartum, and thereafter daily gains increased slowly. After 7 weeks, calf daily gains for first lactation were consistently lower than those for the other lactations.

Relationship between milk yield and calf growth

Linear relationships between milk yield and calf weight gain are presented in table 4. Signifi-

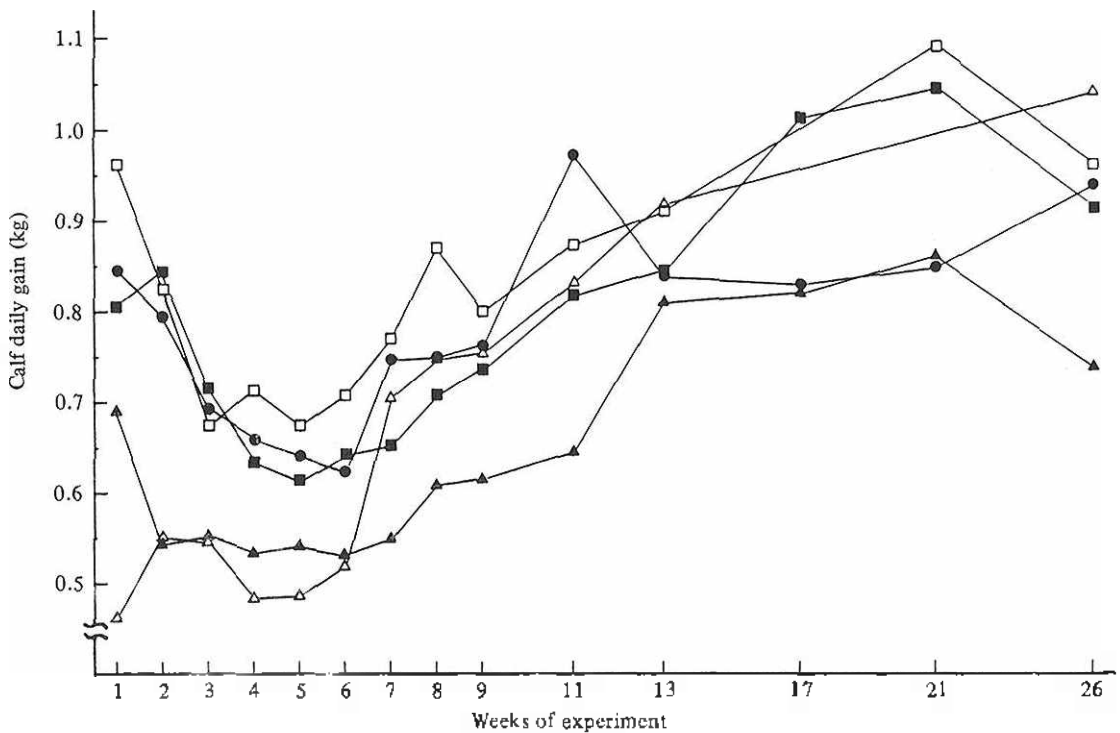


Figure 2. Calf daily gain adjusted to a male calf basis between experiment weeks for different lactations. ▲, 1st lactation; ■, 2nd lactation; ●, 3rd and 4th lactations; □, 5th to 7th lactations; △, 8th and 9th lactations.

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TABLE 4. LINEAR RELATIONSHIPS BETWEEN MILK YIELD (Y, KG) AND CALF DAILY GAIN (X, KG)

Experiment week	No.	Y = Daily milk yield X = Calf DG between experiment weeks			Y = Cumulative milk yield X = Calf DG from birth to experiment week		
		a	b	r	a	b	r
1	69	3.88	2.21	0.51***	29.7	14.3	0.43***
2	73	3.23	3.05	0.68***	40.8	51.0	0.68***
3	73	2.51	4.38	0.73***	44.1	101.4	0.79***
4	74	1.80	5.40	0.73***	40.3	163.6	0.84***
5	74	2.17	4.98	0.67***	37.0	226.8	0.87***
6	74	1.90	5.24	0.66***	32.5	291.0	0.89***
7	74	2.10	4.14	0.53***	25.1	353.6	0.89***
8	74	2.19	3.57	0.47***	12.5	419.1	0.90***
9	66	2.16	3.44	0.51***	9.3	469.3	0.88***
11	33	2.30	2.53	0.50**	29.4	517.3	0.85***
13	68	3.00	1.35	0.24	7.7	617.6	0.78***
17	31	4.47	-0.72	-0.22	124.1	578.5	0.65***
21	31	3.75	-0.26	-0.08	103.2	713.9	0.60***
26	63	2.49	0.96	0.26	256.4	666.3	0.44***

** $p < 0.01$, *** $p < 0.001$

a intercept

b regression coefficient

r correlation coefficient

cant positive relationships were found between daily milk yield of each week and calf daily gain from the previous experiment week. The regression and correlation coefficients reached maximum in 3 to 4 weeks, and then decreased. In 13 to 17 and 17 to 21 weeks the correlation values tended to be negative.

The correlation coefficients between cumulative milk yield and calf daily gain from birth to each experiment week, ranged from 0.43 to 0.90, and were higher than those between daily milk yield and calf daily gain between experiment weeks. The maximum correlation coefficient was recorded between 8 weeks cumulative milk yield and calf daily gain from birth to 8 weeks. Figure 3 shows the least-squares means for daily milk yield and calf daily gain for different lactations.

Discussion

In Japanese Black cows, the shape of the lactation curve was essentially a straight line. This linear decrease in daily milk yield without a peak lactation was similar to that in studies in cross-

bred beef cows (Gaskins and Anderson, 1980) and in Hereford cows (Holloway et al., 1985). Time of peak lactation occurred several weeks postpartum for beef breeds in the reports of Russel et al. (1979), Somerville et al. (1983) and Jenkins and Ferrel (1984). In a previous study, Shimada et al. (1987) reported time of peak lactation as approximately 5 weeks in second lactations for Japanese Polled cows developed from a cross between Japanese Black cows and Angus bulls in the earlier part of the 20th century; this breed also had a greater daily milk yield after the time of peak yield than Japanese Black cows. These results suggested that different breeds have characteristic lactation patterns.

The levels of daily milk yield recorded in this study were lower than those in Hereford x British Friesian cows (Somerville et al., 1983), Simmental x Angus and Jersey x Angus cows (Gaskins and Anderson, 1980), but were similar to levels in Hereford and Angus cows (Holloway et al., 1985).

Daily milk peak yields for first, second, third, fourth and fifth to ninth lactations ranged from 2.1 to 6.6, 4.5 to 8.0, 4.5 to 8.6, 4.3 to 8.2 and

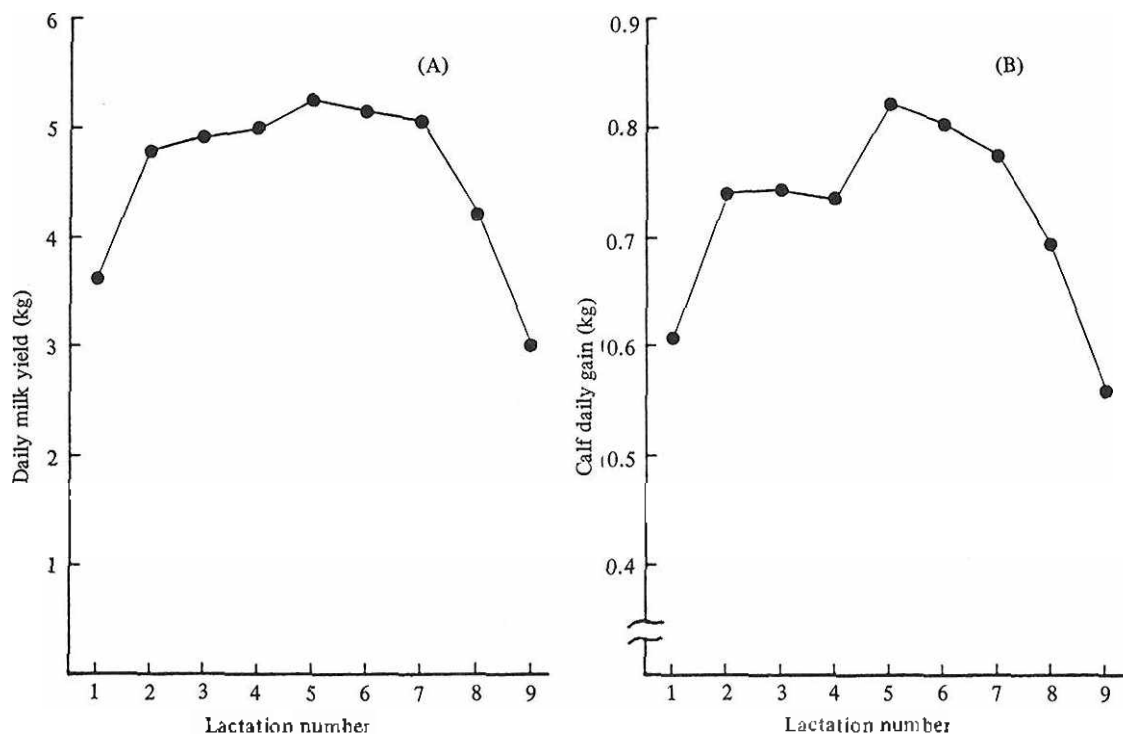


Figure 3. Least-squares means for daily milk yield (A) and calf daily gain (B) for different lactations in Japanese Black cows and calves.

3.4 to 8.1 kg, respectively, for individual cows. This difference between cows within lactations was one of the reasons for high repeatability estimate of 0.60 (table 3). The repeatability of daily milk yield estimated in this study was similar to the estimates of 0.55 to 0.79 reported by Williams et al. (1979).

The lower calf birth weight and milk yield of autumn-calving cows were probably related to lower cow weights compared to those calving in the other seasons. This in turn appeared to be related to insufficient nutrition before calving because of lower yield of pasture due to low rainfall and high temperature in summer. Russel et al. (1979) suggested that severe undernourishment in late pregnancy reduced calf birth weight and subsequent production of the cows.

The decrease in calf daily gain between earlier experiment weeks suggested an insufficient level of nutrition because of the linear decrease in daily milk yield. Although the pattern of daily milk yield change for first lactation was similar to that for eighth to ninth lactation, the pattern of calf daily gain was different for two groups.

Calves for eighth to ninth lactations grew more rapidly in the earlier stages of lactation than those for first lactation. The main factor affecting this increase in the earlier stage could be the difference of approximately 8 kg in calf birth weight.

The maximum correlation coefficient between daily milk yield and calf daily gain recorded in 3 to 4 weeks was 0.73; correlations decreased as lactation progressed. While calf feed intake was not tested in the present study, the negative correlation coefficients suggested that calves from lower milk yield cows consumed more hay and creep ration during the time of peak daily gain at 17 to 21 weeks. Clutter and Nielsen (1987) showed that the correlation of milk intake with subsequent postweaning gain tended to be negative. The correlation coefficients between cumulative milk yield and calf daily gain from birth were higher than those between daily milk yield and calf daily gain between experiment weeks. The latter seemed to be influenced primarily by scours, general health of calf and short term weather.

It was concluded that the milk yield in

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Japanese Black cows was low, especially in earlier stages of lactation. However, the repeatability estimate for milk yield was high, which suggested that culling low producing heifers or cows will improve average milk yield of the herd.

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