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# Comparison on the Growth Characteristics between Calves of Two Different Japanese Beef Breeds Suckled by Japanese Shorthorn Dams

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## Abstract

The growth characteristics of five male Japanese Black calves that were produced by embryo transfer to, born from, and nursed by Japanese Shorthorn surrogate dams (BS-group) were compared with those of five male Japanese Shorthorn calves that were delivered from dams of the same breed after natural mating (SS-group). The birth weights of the BS-group calves were lower ($P < 0.01$) than those of the SS-group calves. During the first two months, the daily weight gain of the SS-group calves was greater ($P < 0.05$) than that of the BS-group calves. However, between the third and fourth months, the daily weight gain of the BS-group calves was greater ($P > 0.05$). During the first two months, the chest girth was smaller ($P < 0.05$) in the BS-group calves than in the SS-group calves, but was similar in both groups by the age of four months. Although the gains in chest depth, body length, and withers height of the BS-group calves were inferior to those of the SS-group calves during the first two months, these gains were all superior to those of the SS-group calves during the next two months. Trends in age-related changes in plasma total cholesterol concentrations significantly differed between both groups. The SS-group dams lost much more weight during early lactation than did the BS-group dams ($P > 0.05$). No difference was observed in the blood components of the dams in either group. In summary, the BS-group calves were relatively small at birth, and their growth performance was inferior to that of the SS-group calves during the first two months. At around two months of age, the Japanese Black embryo-transfer calves began to suckle larger amounts of milk from their surrogate dams and showed rapid growth that was comparable to that of larger framed Japanese Shorthorn calves.

**Discipline:** Animal Science
**Additional key words:** cow-calf grazing, Japanese Black cattle, lactation, *Wagyu*, weight gain

## Introduction

Japanese Black cattle and Japanese Shorthorn cattle are breeds of *Wagyu* (Japanese beef cattle). The Japanese Black, known for its capacity to produce highly marbled beef, is raised throughout Japan and constitutes more than 90% of *Wagyu* raised and fattened in Japan. Due to the demand for high marbling in the Japanese domestic market, the Japanese Black breed became the dominant *Wagyu* breed. In contrast, the Japanese Shorthorn is raised mainly in the northern region (*Tohoku*) of Japan. This breed was improved by crossbreeding imported Shorthorn bulls with the indigenous *Nanbu* cattle that were kept in upland areas of the *Tohoku* region (Takayasu 1983). The Japanese Shorthorn is particularly efficient at using all the grass and other resources of an area, allowing it to be raised on a smaller parcel of land.

Japanese Shorthorn cows have the highest milk yield capability of the *Wagyu* breeds. Over the course of 180 days, the milk yield of Japanese Shorthorn cows is

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1,500-2,000 kg (Shuji et al. 1997, Shingu et al. 2002), or about twice the amount yielded by Japanese Black cows at 500-1,000 kg (Shimada et al. 1988, Shingu et al. 2002). The growth of Japanese Shorthorn calves raised by Japanese Shorthorn dams is superior (NARO 2008), suggesting that Japanese Shorthorn cows may have particularly strong abilities to nurture calves. In our previous study (Yamaguchi et al. 2013), we reported that Japanese Black calves produced by embryo transfer to, born from, and nursed by Japanese Shorthorn surrogate dams in a cow-calf grazing system grew faster than did Japanese Black calves that were conceived by artificial insemination, nursed by Japanese Black dams, and reared in a cowshed. This result suggested that the maternal effect of Japanese Shorthorn surrogate dams was positive for the growth of Japanese Black embryo-transfer calves during the early suckling stage.

The superior growth of Japanese Black calves produced by embryo transfer, however, was possibly due to the calves' own inherent abilities to grow, as well as the maternal effect of the Japanese Shorthorn surrogate dams. Few reports have compared the growth of Japanese Black calves with that of Japanese Shorthorn calves when both breeds receive the same large amount of milk. In previous studies, embryo-transferred calves of different breeds were influenced in various ways by the recipient dams (Guilbault et al. 1990, Isogai et al. 1994). It is also unclear how calving and nursing Japanese Black embryo-transfer calves affect Japanese Shorthorn dams.

The present study compared the growth of Japanese Black embryo-transfer calves and Japanese Shorthorn calves suckling from Japanese Shorthorn dams in a cow-calf grazing system, in order to clarify the growth characteristics of the Japanese Black embryo-transfer calves and refine the system.

## Materials and methods

### 1. Animals

All animal treatments were approved by the Animal Care and Use Committee of the Tohoku Agricultural Research Center. Male Japanese Black calves that were produced by embryo transfer to and born from Japanese Shorthorn surrogate dams (n = 5, BS-group), and male Japanese Shorthorn calves that were produced by natural mating and born from Japanese Shorthorn dams (n = 5, SS-group) were used in this study. The embryo transfer procedure followed that of Yamaguchi et al. (2013). Of the 26 Japanese Shorthorn dams, eight became pregnant following embryo transfer (31%), later producing five male and three female Japanese Black calves. The five male Japanese Black embryo-transfer calves were used in the present study. For the second group of cattle, Japanese Shorthorn calves were produced by natural mating of Japanese Shorthorn cows with a Japanese Shorthorn bull. Both groups of Japanese Shorthorn dams became pregnant on grazing land during the period from July to September. The mean age at the calving stage, prepartum body weight, and parity of Japanese Shorthorn dams in the BS-group were 4.5 ± 1.9 years old, 642.2 ± 116.0 kg, and 2.6 ± 1.1, respectively, and in the SS-group were 4.1 ± 0.8 years old, 651.6 ± 72.3 kg, and 2.0 ± 0.7, respectively.

### 2. Feeding

Both groups of dams received the same type and amount of feed from the initiation of pregnancy to the completion of the first four months postpartum. The local grazing season lasts from the end of April to the beginning of November; during this time, the dams were grazed on pastureland without supplemental feed. During the remainder of the year, they were fed hay silage *ad libitum* with 1 kg of concentrated feed (TDN 68%, CP 15%) twice a day in a cowshed. During both seasons, water and mineral salt were supplied *ad libitum*. Male Japanese Black embryo-transfer calves in the BS-group were born between May 8$^{th}$ and June 24$^{th}$, and Japanese Shorthorn male calves in the SS-group were born between May 7$^{th}$ and July 3$^{rd}$. Both groups of dams and calves experienced the same grazing conditions. They were allowed to graze on 4.8 ha of pastureland that was predominantly covered by Kentucky bluegrass (*Poa pratensis*), and were not given supplemental feed. The pastureland was separated into three sections, between which the animals were rotated according to grass quantity. Again, water and mineral salt were supplied *ad libitum*. The body weight of each animal was measured weekly in both groups. The chest girth, chest depth, body length, and withers height of all calves were measured monthly.

### 3. Sampling and analysis of blood

Blood samples (10 ml) were collected biweekly from calves and monthly from dams from the external jugular vein into tubes containing sodium heparin (Terumo Co., Ltd., Tokyo). Samples were immediately chilled on ice and centrifuged at 1,600 × g at 4°C for 25 min. After centrifugation, plasma was aspirated and stored at −30°C until analysis. Plasma concentrations of urea nitrogen (BUN), glucose (GLU), and total cholesterol (T-CHO) were determined using commercially available colorimetric kits (Quick Auto Neo BUN, Quick Auto Neo GLU-HK, and Quick Auto Neo T-CHO II, respectively; Shino-Test Co., Ltd., Tokyo, Japan) and a Hitachi 7070 auto-analyzer (Hitachi, Ltd., Tokyo, Japan). Intra- and inter-assay coefficients of variation were 4.8 and 7.7% for BUN, 5.2 and 6.3% for GLU, and 5.2 and 8.3% for T-CHO, respectively.

### 4. Statistical analysis

Data were analyzed using a repeated measurement design with the general linear model (GLM) procedure of the SAS system (software release 9.3; SAS Institute, Cary, NC, USA). All data are presented as mean ± SE and $P < 0.05$ was considered significant. From birth to four months of age, the mean body weight, chest girth, chest depth, body length, and withers height of calves were calculated for each group. The weights of dams were calculated relative to the calving body weight. Blood components were divided by month and calculated. The significance of differences among means of the respective variables was determined using Student *t*-tests or Duncan's multiple range tests.

## Results

### 1. Body weight changes and daily weight gain of calves

Figure 1 shows the body weight of the calves from birth to four months of age. The birth body weight of the SS-group calves (44.3 ± 6.9 kg) was significantly higher than that of the BS-group calves (32.2 ± 2.6 kg) ($P < 0.01$). The weights of the SS-group calves at one, two, and three months after birth were 82.7 ± 8.1 kg, 115.9 ± 12.1 kg, and 150.2 ± 12.1 kg, respectively. The SS-group body weights were significantly higher ($P < 0.01$ or $P < 0.05$) than those of the BS-group at one, two, and three months of age (65.8 ± 2.9 kg, 96.6 ± 10.0 kg, and 129.0 ± 12.6 kg, respectively). Figure 2 shows the monthly calculated average daily weight gain (DG) of both groups for each month. In the first month, the DG of the SS-group (1.35 ± 0.18 kg/day) was significantly larger than that of the BS-group (1.12 ± 0.04 kg/day) ($P < 0.05$). During the calves' first two months, the DG of the SS-group calves was greater ($P < 0.05$) than that of the BS-group calves. However, between the third and fourth months, the DG of the BS-group calves (1.08 ± 0.39 kg/day) was greater ($P > 0.05$) than that of the SS-group calves (0.99 ± 0.11 kg/day). The DG of the BS-group calves exceeded 1.0 kg until four months of age. This DG is superior to the standard DG level of this breed (0.59-0.97 kg; NARO 2008).

### 2. Changes in physical size of calves

Table 1 lists the growth of chest girth, chest depth,

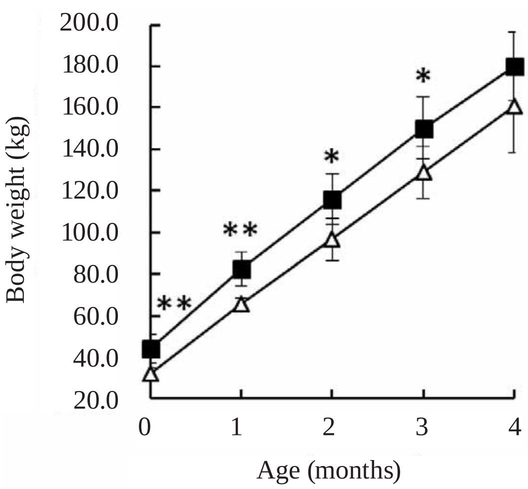


**Fig. 1. The body weights of Japanese Black (JB) calves born from and nursed by Japanese Shorthorn (JS) dams (BS-group), and of JS calves born from and nursed by JS dams (SS-group) during the first four months of life**

—△— BS-group: JB calves born from JS dams
—■— SS-group: JS calves born from JS dams
The data are shown as the mean ± SD, and * ($P < 0.05$) and ** ($P < 0.01$) indicate significant effects between the groups.

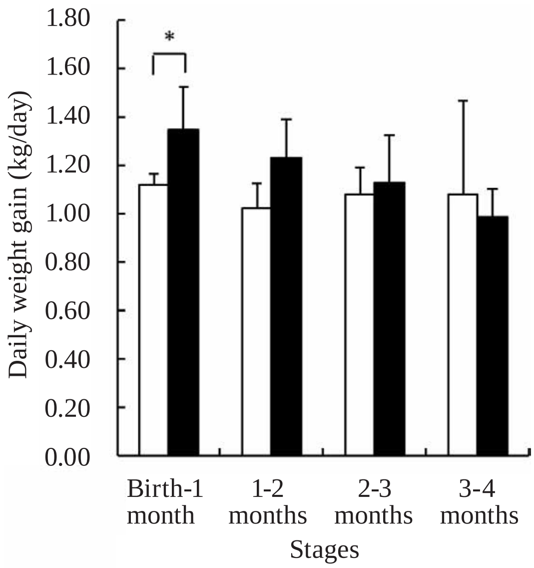


**Fig. 2. The monthly daily weight gain of Japanese Black (JB) calves born from and nursed by Japanese Shorthorn (JS) dams (BS-group), and of JS calves born from and nursed by JS dams (SS-group)**

□ BS-group: JB calves born from JS dams
■ SS-group: JS calves born from JS dams
The data are shown as the mean + SD, and * ($P < 0.05$) indicates significant effects between the groups.

**Table 1. Changes in body measurements of Japanese Black calves born from and nursed by Japanese Shorthorn (JS) dams (BS-group), and of JS calves born from and nursed by JS dams (SS-group)**

| | Group | Age (months) | | | Daily gain (/day) | |
|---|---|---|---|---|---|---|
| | | Birth | 2 | 4 | Birth-2 months | 2-4 months |
| Body weight (kg) | BS | 32.2 ± 2.6[c] | 96.6 ± 10.0[a] | 160.9 ± 22.3 | 1.07 ± 0.14[a] | 1.07 ± 0.22 |
| | SS | 44.3 ± 6.9[d] | 115.9 ± 12.1[b] | 180.1 ± 16.4 | 1.19 ± 0.16[b] | 1.07 ± 0.12 |
| Chest girth (cm) | BS | 77.7 ± 1.5 | 104.3 ± 2.5[a] | 126.5 ± 3.4 | 0.44 ± 0.02 | 0.37 ± 0.06[a] |
| | SS | 82.1 ± 6.8 | 113.0 ± 6.4[b] | 126.9 ± 3.9 | 0.50 ± 0.09 | 0.25 ± 0.06[b] |
| Chest depth (cm) | BS | 27.8 ± 1.1 | 38.5 ± 0.9 | 46.2 ± 1.9 | 0.18 ± 0.02 | 0.13 ± 0.04 |
| | SS | 29.2 ± 4.3 | 40.3 ± 2.6 | 47.0 ± 2.2 | 0.18 ± 0.08 | 0.11 ± 0.03 |
| Body length (cm) | BS | 65.2 ± 1.0 | 87.3 ± 0.8 | 103.4 ± 4.3 | 0.37 ± 0.03 | 0.27 ± 0.07 |
| | SS | 65.1 ± 3.5 | 91.4 ± 4.1 | 106.7 ± 3.1 | 0.44 ± 0.07 | 0.25 ± 0.06 |
| Withers height (cm) | BS | 72.5 ± 2.5 | 86.0 ± 1.5 | 100.2 ± 2.1 | 0.22 ± 0.02 | 0.24 ± 0.03 |
| | SS | 73.8 ± 5.9 | 88.9 ± 3.8 | 100.9 ± 3.7 | 0.25 ± 0.07 | 0.20 ± 0.04 |

[a, b, c, d]: Different letters indicate significant differences between groups within each stage (a, b: $P < 0.05$; c, d: $P < 0.01$).

body length, and withers height of the calves from birth to four months of age. The chest girth in the SS-group calves was 4.4 cm greater ($P > 0.05$) than in the BS-group calves at birth. Even at one month of age, the chest girth of the SS-group calves was significantly greater ($P < 0.01$) than that of the BS-group calves (100.1 ± 4.5 vs. 92.1 ± 2.4 cm). Again, at two months of age, the chest girth of the SS-group calves (113.0 ± 6.4 cm) was greater ($P < 0.05$) than that of the BS-group calves (104.3 ± 2.5 cm). However, there was no difference ($P > 0.05$) between the groups in the chest girth of calves at four months of age. The monthly calculated average daily gain of chest girth of the SS-group calves was greater ($P > 0.05$) than that of the BS-group calves in the first two months, but during the next two months, from two to four months of age, the daily gain of chest girth in the BS-group calves (0.37 ± 0.06 cm/day) was greater ($P < 0.05$) than that of the SS-group calves (0.25 ± 0.06 cm/day). The chest depth was greater in the SS-group calves than in the BS-group calves throughout the experimental period, but was only statistically significant at one month of age ($P < 0.05$). No difference in body length was observed between the groups at birth. However, by three months of age, the body length of the SS-group calves was significantly greater ($P < 0.05$) than that of the BS-group calves (100.2 ± 2.1 cm vs. 96.6 ± 2.5 cm). Although the withers height was greater in the SS-group calves than in the BS-group calves throughout the experimental period, this difference in height was not significant from birth to four months of age.

### 3. Blood components of calves

Table 2 lists the plasma concentrations of BUN, GLU, and T-CHO of the calves. The BUN concentration of both groups of calves showed similar time-dependent changes. Although the BUN concentrations of the BS-group calves were higher than those of the SS-group calves throughout the experimental period, the differences were not significant from birth to four months of age. The GLU concentrations tended to decrease with growth in both groups. The GLU concentrations in the BS-group calves between the first and second months and between the third and fourth months were 127.2 ± 9.4 mg/dl and 108.9 ± 9.9 mg/dl, respectively. The BS-group GLU concentrations were significantly higher ($P < 0.05$) than those of the SS-group calves at the same stages (113.7 ± 8.9 mg/dl and 90.9 ± 8.8 mg/dl, respectively). No difference in T-CHO concentration was observed between the groups from birth to the first month of age. However, between the second and third months, the T-CHO concentration in the BS-group calves was higher ($P < 0.05$) than that in the SS-group calves (150.0 ± 22.5 mg/dl vs. 122.1 ± 27.2 mg/dl). Moreover, the T-CHO concentration in the BS-group calves between the third and fourth months was significantly higher ($P < 0.01$) than that in the SS-group calves (173.9 ± 31.6 mg/dl vs. 124.4 ± 31.8 mg/dl).

### 4. Body weight changes of dams

Figure 3 shows the dam body weight relative to the calving body weight for each week of the experimental

**Table 2. Plasma concentrations of blood urea nitrogen, glucose, and total cholesterol of Japanese Black calves born from and nursed by Japanese Shorthorn (JS) dams (BS-group), and of JS calves born from and nursed by JS dams (SS-group) at four stages after birth**

| | | Stages | | | |
|---|---|---|---|---|---|
| | Group | Birth-1 month | 1-2 months | 2-3 months | 3-4 months |
| Blood urea nitrogen (mg/dl) | BS | 12.4 ± 4.2 | 10.5 ± 2.3 | 12.9 ± 3.1 | 15.6 ± 2.8 |
| | SS | 11.4 ± 2.0 | 9.7 ± 1.8 | 11.1 ± 2.7 | 13.2 ± 4.4 |
| Glucose (mg/dl) | BS | 133.9 ± 18.8 | 127.2 ± 9.4[a] | 112.3 ± 9.0 | 108.9 ± 9.9[a] |
| | SS | 126.5 ± 18.5 | 113.7 ± 8.9[b] | 104.0 ± 10.7 | 90.9 ± 8.8[b] |
| Total cholesterol (mg/dl) | BS | 104.8 ± 32.5 | 137.4 ± 22.2 | 150.0 ± 22.5[a] | 173.9 ± 31.6[c] |
| | SS | 101.1 ± 23.1 | 122.3 ± 11.6 | 122.1 ± 27.2[b] | 124.4 ± 31.8[d] |

[a, b, c, d]: Different letters indicate significant differences between groups within each stage (a, b: $P < 0.05$; c, d: $P < 0.01$).

period. At calving from immediately prepartum, the body weights of the SS-group dams and BS-group dams decreased by 8.2% and 7.0%, respectively. The body weights of four of the five SS-group dams were lower than their calving body weights at two months postpartum. In contrast, only one of the five BS-group dams had a body weight at two months postpartum that was lower than her calving body weight. The body weights of the remaining four BS-group dams were greater than their calving weights at two months postpartum. Two months postpartum, the body weight of the SS-group dams was 3.2% lower than the calving body weight, whereas the body weight of the BS-group dams had increased by 3.3%.

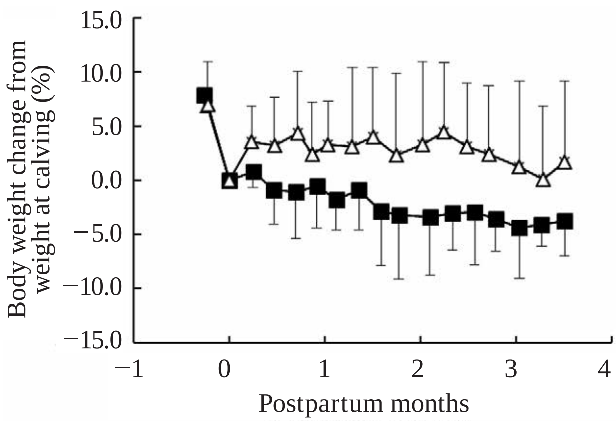


**Fig. 3. Body weights of Japanese Shorthorn dams (JS) that gave birth to and nursed Japanese Black (JB) calves (BS-group), and of JS dams that gave birth to and nursed JS calves (SS-group) from prepartum to the completion of four months postpartum. Weights are expressed relative to body weight at calving.**
△ BS-group: JS dams nursed JB calves
■ SS-group: JS dams nursed JS calves

### 5. Blood components of dams

Table 3 lists the plasma concentrations of BUN, GLU, and T-CHO of the dams. The BUN, GLU, and T-CHO concentrations of the dams in both groups showed similar time-dependent changes. As time since calving increased, the concentrations of BUN and T-CHO increased, but the GLU concentration did not change much. No differences in plasma concentrations of BUN, GLU, and T-CHO were observed between the two groups of dams.

## Discussion

Several studies have shown that the growth performance of Japanese Shorthorn cattle is superior to that of Japanese Black cattle under grazing conditions (Sawazaki et al. 1974, Watanabe et al. 1974). Matsukawa et al. (1979) calculated growth curve equations for Japanese Shorthorn and Japanese Black cattle, and suggested that Japanese Shorthorns were always bigger at the same chronological age. These studies suggested that Japanese Shorthorns have superior growth performance to that of Japanese Blacks under various conditions. However, few studies have compared the growth of Japanese Black and Japanese Shorthorn calves during the early suckling stage when both are reared under the same feeding conditions. In the present study, we compared the growth of Japanese Black embryo-transfer calves and Japanese Shorthorn calves when both were raised under the same suckling conditions in a cow-calf grazing system.

The birth weight of calves is of critical importance

**Table 3. Plasma concentrations of blood urea nitrogen, glucose, and total cholesterol of Japanese Shorthorn dams (JS) that gave birth to and nursed Japanese Black calves (BS-group), and of JS dams that gave birth to and nursed JS calves (SS-group) at four stages after calving**

| | | Stages | | | |
|---|---|---|---|---|---|
| | Group | Calving-1 month | 1-2 months | 2-3 months | 3-4 months |
| Blood urea nitrogen (mg/dl) | BS | 20.4 ± 3.4 | 24.0 ± 2.3 | 27.5 ± 2.5 | 31.0 ± 2.4 |
| | SS | 18.1 ± 3.8 | 24.5 ± 3.1 | 26.7 ± 3.1 | 27.7 ± 5.1 |
| Glucose (mg/dl) | BS | 67.2 ± 3.6 | 63.7 ± 4.3 | 63.8 ± 1.2 | 64.5 ± 3.3 |
| | SS | 69.9 ± 5.2 | 63.9 ± 3.5 | 67.2 ± 4.8 | 64.7 ± 5.6 |
| Total cholesterol (mg/dl) | BS | 101.4 ± 25.4 | 115.9 ± 19.9 | 123.4 ± 17.3 | 145.0 ± 28.5 |
| | SS | 95.0 ± 19.9 | 120.3 ± 28.0 | 131.5 ± 43.5 | 130.4 ± 29.7 |

to the beef cattle industry, and is affected by various factors (Holland & Odde 1992). In this study, a significant difference was observed in birth weight between the two groups of calves. This result suggests that in the same uterine environment, both embryonic development and fetus growth between the two breeds was different. Additionally, calves that are too small at birth may lack vigor, whereas calves that are too large at birth may cause varying degrees of dystocia (Holland & Odde 1992). Although the birth weight of the BS-group calves was slightly lower than the standard weight (NARO 2008), the BS-group calves were not unusually small or very weak. The SS-group calves had slightly larger birth weight than the standard weight, but were not overly large, thereby avoiding dystocia during calving. In primiparous dams of the SS-group, although the average ratio of calf birth weight to the prepartum body weight of the dam was approximately 8%, midwifery was not needed. This result suggested that dystocia rarely occurs during the calving stage of Japanese Shorthorn dam, despite the relatively large calves of this breed.

During the first two months after birth, the DG of the SS-group calves was greater ($P < 0.05$) than that of the BS-group calves, as was the chest girth of the BS-group calves ($P < 0.05$). The vigor and greater nursing needs of the larger SS-group calves probably stimulated greater milk production in the SS-group dams. These results were probably affected by differences in birth weight as well as differences related to the breed. Thus, further examination is necessary to clarify how the calf breed affects milk production. Between the third and fourth months, the DG of the BS-group calves was greater than that of the SS-group calves, and at the age of four months, the chest girth was similar in both groups of calves. This finding suggests that the growth performance of the BS-group calves from birth to two months is inferior to that of the SS-group calves of the same age, but after three months of age, the growth of the BS-group calves is similar to that of the SS-group calves.

Between the first and second months, the GLU concentrations of the BS-group calves were significantly higher ($P < 0.05$) than those of the SS-group calves. However, the monthly DG of the SS-group calves was greater ($P < 0.05$) than that of the BS-group calves. This result conflicted with that of previous reports, which associated high GLU concentrations in calves with fast growth (Kitchenham et al. 1975, Sato et al. 1989). Even though the GLU concentration was high in the BS-group calves, weight gain likely plateaued because the weight-gain potential of the BS-group calves had reached its upper limit. No difference in the T-CHO concentration was observed between both groups shortly after birth, but a significant difference between the groups gradually became evident over time. The T-CHO concentration of all BS-group calves increased with growth. Meanwhile, for three SS-group calves, the T-CHO concentration barely changed during the experimental period. Nestel et al. (1978) reported that the serum cholesterol concentration in calves increased due to increased fat and energy intake. In the present study, the milk fat concentration and energy content of the grass ingested by calves in both groups was likely similar. Therefore, the digestion and utilization of fat by calves during the suckling stage probably differed between the groups. Growth during the early suckling stage is affected not only by milk intake but also by fat intake (Christian et al. 1965). The DG of the BS-group calves between the third and fourth months was probably associated with the relatively high total cholesterol concentration in their plasma.

The milk yield of Japanese Shorthorn cows is affected by body weight, parity, and breeding environment (Terada et al. 1979). In this study, the dams of both groups received the same diet from the initiation of pregnancy to the completion of the first four months postpartum, and the mean age, parity, and body weight of the dams in both groups were similar. Therefore, dams in both groups probably had a similar milk-yield capacity and similar nutrient content in their milk. However, the SS-group dams lost more weight during early lactation than did the BS-group dams. When nutrient intake is insufficient for milk production, cows that produce high milk yields compensate by mobilizing body fat. The vigor and greater nutritional needs of the larger SS-group calves probably stimulated the SS-group dams to devote a greater amount of nutrients to milk production, mobilizing fat, and reducing their fat stores.

The milk yield of the SS-group dams and the milk consumption of the SS-group calves probably exceeded those of the BS-group dams and calves. A key factor in calf growth is the amount of milk yielded by their dams (Cutter & Nielsen 1987, Shimada et al. 1988). There is a high correlation (r = 0.88, $P < 0.01$) between the amount of milk consumed and DG for calves up to eight weeks of age (Kyuma et al. 1979). Therefore, the significant difference observed in the DG of calves from birth to two months of age was probably affected by the different amounts of milk rather than by the different breeds of the calves. Conversely, no differences were observed between the dams of both groups in plasma concentrations of BUN, GLU, and T-CHO. It was probably normal that the concentrations of BUN and T-CHO of dams in both groups tended to increase over time after calving. Although the pattern of change in body weight differed between the BS-group and SS-group dams, their homeostasis probably was not affected.

In summary, although Japanese Shorthorn cattle have a larger uterine capacity than Japanese Black cattle, the BS-group calves were smaller at birth ($P < 0.01$). In addition to being relatively small at birth, the growth performance of the BS-group calves was inferior to that of the SS-group calves during the first two months. Japanese Black cattle have high genetic diversity and display a wide range of birth weights and body sizes at maturity (Nomura et al. 1987). At about two months of age, Japanese Black embryo-transfer calves had grown sufficiently to allow them to suckle large amounts of milk from their surrogate dams, and to show rapid growth that was comparable to that of large-framed Japanese Shorthorn calves. In contrast, the daily weight gain of the BS-group calves exceeded 1.0 kg until they reached four months of age. They showed faster growth than their reference population of naturally reared Japanese Black calves during the entire suckling period. The nutrition environment of the fetal and neonatal period is likely to affect subsequent growth. Thus, there is a need to study the future growth of Japanese Black cattle produced by embryo transfer to, born from, and nursed by Japanese Shorthorn surrogate dams. As Japanese Black calves command a high price on the Japanese market, we conclude that the production system used in this experiment can improve the profitability of herds in upland Japan.

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