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Factors influencing the priority of access to food and their effects on the carcass traits for Japanese Black (Wagyu) cattle

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The factors influencing the priority of access to food and the effects of the priority of access to food on their carcass traits were analyzed for Japanese Black (Wagyu) cattle in a semi-intensive fattening production system. The records of 96 clinically healthy steers and heifers were analyzed. The calves at ~3 to 4 months of age were allocated to pens with four animals per pen; all four animals in the same pen were of the same sex and of similar body size. The ranking of the animals' priority of access to food (1^{st}, 2^{nd}, 3^{rd} and 4^{th}), which was determined by the farm manager, was used as an indicator of social dominance in the present study. Four models including sire line, maternal grandsire line and the difference in the animals' birth dates as fixed effects were used to analyze factors influencing the priority of access to food. Ranking was represented by ordinal scores (highest = 4, lowest = 1) in Model 1, and the binary scores were assigned in Model 2 (highest = 1; 2^{nd}, 3^{rd} and 4^{th} = 0), Model 3 (1^{st} and 2^{nd} = 1; 3^{rd} and 4^{th} = 0) and Model 4 (1^{st}, 2^{nd} and 3^{rd} = 1; lowest = 0). The results showed that the difference in the animals' birth dates had a significant effect on the establishment of the priority of access to food in Model 3 ($P < 0.05$), suggesting that animals born earlier may become more dominant in the pen. The maternal grandsire line tended to affect the social rank score in Models 2 and 3 ($P < 0.10$). Our results indicated that the maternal grandsire line may affect the temperament of calves through their mothers' genetic performance and thereby more aggressive calves may be more dominant and have higher priority of access to food. On the other hand, there was a significant effect of the priority of access to food on beef marbling score (BMS; $P < 0.05$), and the priority of access to food also tended to influence the carcass weight ($P = 0.09$). The highest BMS was observed for animals with the first rank of the priority of access to food ($P < 0.05$), and the higher-ranking animals had the tendency to be heavier carcass than the lower-ranking animals. Our findings emphasized the importance of information about the priority of access to food determined by farmers' own observation on implementing best management practices in small-scaled semi-intensive beef cattle production systems.

Keywords: access to food, carcass weight, Japanese Black cattle, marbling score, social dominance

Implications

The factors influencing the priority of access to food (measured as an indicator of social dominance) and its effects on the carcass were investigated using 96 steers and heifers allocated with four animals in a pen. The animals' birth dates and the maternal grandsire line were significant sources on ranking of the priority of access to food and the animals with the highest priority of access to food had the highest beef marbling score. The finding may open a new avenue for analyzing the effects of the priority of access to food on animal performance under semi-intensive beef cattle production systems.

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Introduction

Social organization in animals relies on dominance relationships, regardless of whether the group is formed naturally or artificially (Hart, 1985). It is known that cattle interact and develop relationships with each other that are of a dominant-subordinate nature, which leads to the establishment of social dominance (Hafez and Bouissou, 1975). There are many factors influencing social dominance in cattle; physical characteristics such as BW, body size and/or height and the presence of horns (Houpt, 2011) and physiological stages such as age, parity, pregnancy, early *postpartum* and lactation (Landaeta-Hernández *et al.*, 2013). In multi-breed herds, breed also appears to be a factor influencing social organization (Landaeta-Hernández *et al.*, 2005).

There have been some studies investigating social dominance and physiological stress (Solano *et al.*, 2004). Social dominance influences fear and stress response to handling of goats (Miranda-de la Lama *et al.*, 2013a) and dominance-related interactions in cattle can cause stress, bruises and physical injuries (Fordyce *et al.*, 2002). In contrast, there are a limited number of studies on the relationships between social dominance and meat quality traits. Partida *et al.* (2007) reported that the social dominance of cattle did not affect the instrumental and sensory traits of meat in intensively managed young Friesian bulls. More recently, Miranda-de la Lama *et al.* (2013b) showed that, although there was a significant relationship between social dominance and stress indicators (as assessed by the cortisol concentration and neutrophil/lymphocyte ratio), significant relationships between social dominance and some sensory traits (e.g. milk odor and flavor, metallic flavor and tenderness) and interaction effects between social dominance and aging for beef odor and overall liking were found in beef bulls of the Gasconne breed.

The intensification of animal production systems has resulted in groups of animals living in close proximity to each other, often competing for limited resources (Val-Laillet *et al.*, 2008). The priority of access to resources (e.g. food) can express dominance as an attribute of dyadic encounters under the concept of social dominance (Drews, 1993). Focusing on feeding behaviors, McPhee *et al.* (1964) reported that high-ranking steers spent a greater total time eating and had longer meals than low-ranking steers in beef cattle. Milanda-de la Lama *et al.* (2011) also mentioned that highly dominant animals could obtain priority resources in intensive production conditions. Although Francis (1988) argued the inadequacy of the definition in which functional accounts of social dominance stress priority of access to resources, the information on the priority of access to food can be relatively easy to be collected by farmers under production situations, therefore, the priority of access to food (feeding order) can be used as an on-site simple attribute of social dominance in intensive beef cattle production systems.

The objective of the present study was to examine the effects of the genetic and phenotypic factors such as sire and maternal grandsire lines and the difference in the animals' birth dates on the priority of access to food determined by farmers' own observation in a small-scaled semi-intensive beef cattle production system in Japanese Black (Wagyu) cattle. Furthermore, as beef grade and carcass prices have been determined by carcass traits (especially beef quality) in Japanese carcass markets, the effects of the priority of access to food on carcass traits were also investigated for the production system.

Material and methods

Handling management and data collection

The data collection was carried out at a cow–calf-feedlot integrated farm of Japanese Black cattle in Shiraoi, Hokkaido (42°33′N, 141°18′E). Average monthly temperature and annual rainfall in the area were 7.2°C and 1497 mm, respectively. At the surveyed farm, 96 calves at around 3 to 4 months of age are allocated to pens with four animals per pen according to age, body size and sex; all four animals in the same pen are thus of the same sex and of similar body size. There was no special consideration on allocation of sires spread to pens. All animals are ordinarily housed in a 3.6 × 6.7 m pen (stocking density of ~6 m^2 per animal) until they are slaughtered. The pen includes a lying area with a roof and sawdust bedding, a 3.6-m-long trough and a water bowl. All animals in each pen were restrictively fed conventional concentrate (corn, barley, wheat bran and soybean meal) and grass silage at the growing stage (i.e. 3 to 12 months), and conventional concentrate and straw at the fattening stage (i.e. 13 to 29 months). Straw and water were provided *ad libitum*.

In the present study, the social rank was determined according to the priority of access to food instead of the ordinary measurements such as social dominant indexes (Langbein and Puppe, 2004). In the farm, as all steers and heifers were identified by ear tags, long-term direct observation of ranking the priority of access to food for each animal in every pen were carried out until the animals were ~13 months of age after weaning. According to our request, the farm manager observed the animals' behavior for 60 to 90 s in every pen when feeding and he recorded the ranking for the priority of access to food for individual animals over the period. The animals that started feeding first in the pen were classified as the first rank, and subsequently, the second, third and fourth animals to feed at the trough were recorded. The rank scores used for the analyses in the present study were determined once at the beginning of the fattening period after every day direct observations, because the farm manager confirmed that the ranking for the priority of access to food had been fairly stable through the fattening period in the previous preliminary observations. In the present study, the records of the individual information (e.g. sex, sire, maternal grandsire), the priority of access to food and the carcass traits from 96 clinically healthy 60 steers and 36 heifers (4 animals × 24 pens) slaughtered from January 2011 to December 2013 were used for the analyses.

Carcass traits

The carcass weight, rib-eye area, rib thickness, subcutaneous fat thickness and marbling score (Japanese beef marbling standard number: BMS) were analyzed. All carcass traits except carcass weight were graded between the sixth and seventh rib sections in accordance with the Japan Meat Grading Association (1989) certified grades. In Japan, the quality of beef carcasses (yield score) has been judged based mainly on the carcass weight and three other carcass traits (the *longissimus* muscle area, rib thickness and subcutaneous fat thickness) at the sixth and seventh rib sections, because these traits are relatively easy to measure and routinely collected in the carcass markets (Hirooka *et al.*, 1996; Maeno *et al.*, 2014).

Table 1 *Descriptive statistics of birth weight, birth height and carcass traits of the 96 animals in the present study*

	Mean	s.d.	Minimum	Maximum
Birth weight (kg)	32.2	3.9	20	40
Birth height (cm)	73.5	2.1	66	78
Slaughter age (day)	877.5	48.1	576	995
Carcass weight (kg)	466.4	47.2	270	562
Rib eye area (cm^2)	57.0	8.1	30	79
Rib thickness (cm)	8.1	0.8	4.4	9.5
Subcutaneous fat thickness (cm)	2.6	0.6	1.3	4.3
BMS number[1]	7.1	2.0	2	11

s.d. = standard deviation.
[1]Japanese beef marbling standard (BMS) number: a 1 to 12-point scale.

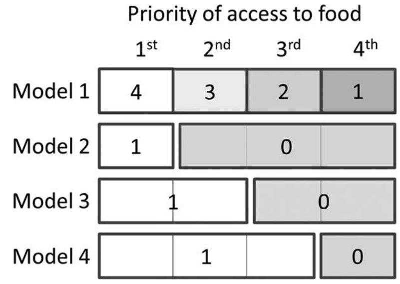

Figure 1 Classification of the priority of access to food and the score in each model. Model 1 assumes that ranking for the priority of access to food was represented by transformed ordinal scores (highest = 4, lowest = 1). The binary scores were assigned in Model 2 (highest = 1st; 2nd, 3rd and 4th = 0), Model 3 (1st and 2nd = 1; 3rd and 4th = 0) and Model 4 (1st, 2nd and 3rd = 1; lowest = 0).

The rib-eye area was measured by grid approximation, and the rib thickness was measured as the distance between the *latissimus* muscle and the pleura membrane measured at the mid-point of the rib ends. The subcutaneous fat thickness was the distance between the *latissimus* muscle and the carcass surface measured on the orthogonal line parallel with the carcass surface from the edge of the *iliocostalis* muscle. The BMS number was scored using a 12-point scale used in Japanese carcass markets: from 12 (the fattest) to 1 (the leanest). Descriptive statistics of birth weight, birth height and carcass traits of the animals are shown in Table 1.

Classification of sire line and maternal grandsire line

In Japan, information on the sire (or maternal grandsire) line of Japanese Black cattle has traditionally been used by farmers to promote the growth rate and meat quality of their cattle, because growth and carcass traits are highly heritable and are genetically determined (Hirooka *et al.*, 1996). In the present study, there were 27 sires and maternal grandsires, which were classified into three sire lines (Fujiyoshi, Kedaka and Tajiri) and four maternal grandsire lines (Fujiyoshi, Kedaka, Tajiri and Shigekane). Ikeda and Fujii (2006) reported that sires of the Fujiyoshi and Kedaka lines have higher growth performance and show a higher incidence of muscular abnormalities compared with the Tajiri line. In contrast, sires of the Tajiri and Shigekane lines show superior marbling (Asada *et al.*, 2004).

Analysis for investigating the factors influencing the priority of access to food

To identify the factors influencing the priority of access to food, the following four models were used (Figure 1). In Model 1, ranking for the priority of access to food was represented by transformed ordinal scores (highest = 4, lowest = 1). In addition, binary scores were used to make clear the differences between ranks (Models 2, 3 and 4), because the four rank scores in Model 1 are ranked variables and the differences between the ranks are not equal; the difference between ranks 1 and 2 may not be the same as the difference between ranks 2 and 3. The binary scores were assigned in Model 2 (highest = 1st; 2nd, 3rd and 4th = 0), Model 3 (1st and 2nd = 1; 3rd and 4th = 0) and Model 4 (1st, 2nd and 3rd = 1; lowest = 0).

The mathematical model for statistical analysis was

$$Y_{ijklm} = \mu + SL_i + ML_j + DBD_k + e_{ijkl}$$

where Y_{ijklm} is the score for the priority of access to food and considered a continuous variable in Model 1 and a binary variable in Models 2, 3 and 4; μ the overall mean, SL_i the fixed effect of the sire line (three sire lines), ML_j is the fixed effect of the maternal grandsire line (four maternal grandsire lines), DBD_k is the fixed effect of the difference in birth date (four categories) and e_{ijkl} is the residual effects associated with observation *ijkl*. The 'difference in birth date (days)' of an animal born first in a pen was set as a reference date (difference = 0), and subsequently the differences in birth date between the first animal and other animals were calculated for every pen.

The data were analyzed using the least squares methods of the GLM procedure of the Statistical Analysis System (SAS, 2008) fitting GLM for Model 1. The analyses in Models 2, 3 and 4 were carried out as generalized linear mixed models (GLIMMIX procedure) in SAS. The binary response variables were modeled with a binomial distribution, and the analysis was carried out with a logit transformation. If the analysis exhibited a significant difference, data were further analyzed by Tukey–Kramer least square means comparisons to discern significant differences among the means ($P < 0.05$).

Analysis for investigating the effect of the priority of access to food on carcass traits

The least squares methods of the GLM procedure of SAS (2008) were used to determine the effect of the priority of access to food on the carcass traits, with the probability differences between the least square means tested using the Tukey–Kramer option. The mathematical model was

$$Y_{ijklmnop} = \mu + PAF_i + Sex_j + SY_k + SS_l + SL_m + ML_n + P(Sex)_{oi} + bx_{ijklmnop} + e_{ijklmnop}$$

where $Y_{ijklmnop}$ is the records of carcass traits, μ the overall mean, PAF_i the fixed effect of ranking for the priority of access to food (four levels: 1 (highest), 2, 3 and 4 (lowest)),

Sex_j the fixed effect of sex (steer and heifer), SY_k the fixed effect of the slaughter year (2011, 2012 and 2013), SS_l the fixed effect of the slaughter season (four seasons), SL_m the fixed effect of the sire line, ML_n the fixed effect of the maternal grandsire line, $P\ (Sex)_{oi}$ the random effect of pen within sex (24 pens), b the partial regression coefficient, $x_{ijklmnop}$ the continuous variable for slaughtered age as a covariant for observation *ijklmnop* and $e_{ijklmnop}$ the residual effects associated with observation *ijklmnop*.

Results

Factors influencing the priority of access to food

A significant effect of the difference in birth date on the establishment of the priority of access to food in Model 3 ($P<0.05$) was observed, whereas there were no significant differences for sire line, birth weight and birth height in all models (Table 2). The effect of the difference in birth date within a pen decreased ($P = 0.05$) when Model 1 was assumed. As shown in Table 3, the scores for the priority of access to food of the animals with earlier birth dates were higher than those of the animals with later birth dates in Models 1 and 3. The maternal grandsire line tended to have an effect on the priority of access to food only in Models 2 and 3. The least square means by the priority of access to food for different maternal grandsire lines in the models are presented in Table 4. In Model 2, the animals with the Tajiri maternal grandsire line tended to have a higher priority of access to food compared with the animals with other maternal grandsire lines. In Model 3, the animals with the Kedaka maternal grandsire line showed slightly higher priority of access to food than those with the Tajiri maternal grandsire line. In both Models 2 and 3, the least square means of the Fujiyoshi maternal grandsire line were the lowest priorities of access to food.

Effect of the priority of access to food on carcass traits

The priority of access to food was the significant source of variation in the beef marbling score (BMS; $P<0.05$), and it also tended to influence the carcass weight ($P = 0.09$; Table 5). Sex and slaughter age had significant effects on five and four carcass traits, respectively, and sire line had a tendency to influence the rib thickness ($P = 0.09$), but the other sources of variation had no effects on carcass traits. The least square means of carcass traits in each group classified by the priority of access to food are presented in Table 6. The BMS was the highest in the first group for the priority of access to food ($P<0.05$). The BMS of the first-rank group was 27% higher than that of the second-rank group. In addition, the priority of access to food tended to influence carcass weight ($P = 0.09$). When the priorities of access to

Table 2 *Results of significances for factors influencing the priority of access to food*

	Difference in birth date[1]	Sire line[2]	Maternal grandsire line[3]	Birth weight	Birth height
Model 1[4]	$P<0.10$				
Model 2			$P<0.10$		
Model 3	$P<0.05$		$P<0.10$		
Model 4					

[1]The difference in birth date (x) is represented by the differences in days between the age of the first born animal ($x = 0$) and the remaining animals within the pen.
[2]The lines of steers/ heifers' sires. In this study, there were 27 sires classified four sire lines (i.e. Fujiyoshi, Kedaka, Tajiri and Shigekane).
[3]The lines of steers/heifers' maternal sires same as 'sire line.'
[4]See Figure 1.

Table 3 *The priority of access to food by the difference in birth date within a pen (means ± standard errors)*

		The priority of access to food[2]		
Difference in Birth date × (day)[1]	No. of animals	Model 1[3]	Model 3[4]	
$x = 0$	25[5]	2.74 ± 0.24	0.71 ± 0.47[a]	(0.67 ± 0.10)[6]
$0 < x < 15$	28	2.71 ± 0.24	0.36 ± 0.47[a,b]	(0.59 ± 0.11)
$15 \leqslant x < 30$	24	2.13 ± 0.25	− 0.96 ± 0.50[c]	(0.28 ± 0.10)
$30 \leqslant x$	19	1.97 ± 0.27	− 1.02 ± 0.56[b,c]	(0.26 ± 0.11)
Significance		$P<0.10$	$P<0.05$	

[a,b,c]Different letters in the same column indicate significant differences at $P<0.05$.
[1]The difference in birth date (x) is represented by the differences in days between the age of the first born animal ($x = 0$) and the remaining animals within the pen.
[2]No significant effect of the difference in birth date was observed in Models 2 and 4. The difference of models used is shown in Figure 1.
[3]Analyzed by the GLM procedure.
[4]Analyzed by generalized linear mixed model procedure.
[5]In one group, the two oldest calves shared a birth date.
[6]( ) = Converted means $\hat{\pi}_A$ from logit scale $\left(\hat{\pi}_A = \frac{1}{1+\exp(-0.84)} = 0.70\right)$.

Table 4 *The priority of access to food by each maternal grandsire line within a pen*

Maternal Grandsire line	The priority of access to food[1]			
	Model 2		Model 3	
Fujiyoshi	−3.85 ± 1.12	(0.02 ± 0.02)[2]	−1.35 ± 0.57	(0.21 ± 0.09)
Kedaka	−1.21 ± 0.52	(0.23 ± 0.09)	0.33 ± 0.41	(0.58 ± 0.10)
Tajiri	−0.75 ± 0.71	(0.32 ± 0.15)	0.24 ± 0.63	(0.56 ± 0.16)
Shigekane	−1.37 ± 0.65	(0.20 ± 0.10)	−0.12 ± 0.54	(0.47 ± 0.13)
Significance	$P < 0.10$		$P < 0.10$	

The data are means ± standard errors.
[1]These models were analyzed by generalized linear mixed model procedure. No significant effect of the maternal grandsire line was observed in Models 1 and 4. The difference of models used is shown in Figure 1.
[2]( ) = converted means $\hat{\pi}_A$ from logit scale $\left(\hat{\pi}_A = \frac{1}{1+\exp(-3.85)} = 0.02\right)$

Table 5 *Results of significances for factors influencing carcass traits*

	PAF	Sex	SY	SS	SL[1]	ML[1]	Pen	AGE
Carcass weight (kg)	<0.10	<0.01						<0.01
Rib eye area (cm^2)		<0.05						<0.01
Rib thickness (cm)		<0.05			<0.10			<0.05
Subcutaneous fat thickness (cm)		<0.01						
BMS number[2]	<0.05	<0.05						<0.01

PAF = priority of access to food; SY = slaughter year; SS = slaughter season; SL = sire line; ML = maternal grandsire line; AGE = slaughter age.
[1]In this study, there were 27 sires classified four sire lines (i.e. Fujiyoshi, Kedaka, Tajiri and Shigekane).
[2]Japanese beef marbling standard (BMS) number: a 1 to 12-point scale.

Table 6 *Least square means (± standard errors) of carcass traits of animals ranked as 1st to 4th priority of access to food*

	Priority of access to food				
	1 (n = 24)	2 (n = 24)	3 (n = 24)	4 (n = 24)	Significance
Carcass weight (kg)	463.60 ± 10.41	466.61 ± 9.41	443.85 ± 9.70	442.71 ± 9.79	$P < 0.10$
Rib eye area (cm^2)	55.69 ± 2.17	54.51 ± 1.96	54.97 ± 2.02	55.06 ± 2.04	ns
Rib thickness (cm)	8.16 ± 0.19	8.09 ± 0.17	7.69 ± 0.17	7.89 ± 0.18	ns
Subcutaneous fat thickness (cm)	2.51 ± 0.16	2.64 ± 0.14	2.72 ± 0.15	2.53 ± 0.15	ns
BMS number[1]	7.71 ± 0.50^a	6.05 ± 0.46^b	6.42 ± 0.47^{ab}	6.46 ± 0.47^{ab}	$P < 0.05$

ns = not significant.
[a,b]Different letters in the same row indicate significant differences at $P < 0.05$.
[1]Japanese beef marbling standard (BMS) number: a 1 to 12-point scale.

food were considered to be two (higher and lower) groups, the carcass weights of the first- and second-rank (two higher-rank) animals were significantly heavier than those of the third- and fourth-rank (two lower-rank) animals.

Discussion

Factors influencing the priority of access to food
A significant effect of the difference in birth date on the priority of access to food in Model 3 was found, suggesting that animals with earlier birth dates may be more dominant in each pen. This is not a surprising finding as animals born earlier generally have larger BWs and frames and are thus likely to be dominant. A previous research revealed that social dominance correlated strongly with age (Dickson *et al.*, 1970). Val-Laillet *et al.* (2009) also reported that older multiparous animals were higher-ranking of dominance than younger primiparous ones. Moreover, several studies mentioned that BW was the most significant variable affecting social dominance (Dickson *et al.*, 1967; Stricklin *et al.*, 1980), whereas others showed both age and BW affected social dominance (Landaeta-Hernández *et al.*, 2013). It is reasonable that larger animals take advantage of displacing smaller animals. With regard to the relationship between age and social dominance, our results agreed with the previous reports in spite of the fact that most of the differences in birth date were less than 1 month in the present study.

The maternal grandsire line showed a tendency to influence the priority of access to food in the present study.

The result from Model 2 showed that animals with the maternal grandsire line of Tajiri were more likely to be in the first rank within a pen. Significant effects of breeds on social behavior and consequently social dominance in mixed-breed herds have been reported (Le Neindre, 1989; Landaeta-Hernández *et al*., 2005). Our present results revealed that there was no significant effect of sire lines but the maternal grandsire tended to affect the priority of access to food. This finding indicates that the dam–offspring relationship may have a stronger influence on social dominance traits than the sire–offspring relationship. In recent work, MacKay *et al.* (2013) reported the effect of short-term temperament such as displacement capability on feeding behavior in the home pen for beef cattle. Huzzey *et al.* (2014) pointed out that increased social competition among cattle lead to increased physiological stress, decreased feeding time and thereby decreased dry matter intake. Although neither our study nor other published studies examined the possible maternal effect on temperament of calves in Japanese Black cattle, our present findings indicated that the difference in the maternal grandsire line could influence the social dominance of calves which might be due to the difference in temperament of calves. Further research on this issue in cattle is needed.

As for the method of the statistical analysis, it should be noted that the priority of access to food in a pen was used as a dependent variable in the present study. This type of variable is classified as categorical data with an ordinal scale. Such categorical data have often been analyzed using conventional linear model approaches after transforming or converting to a numerical scale (e.g. the present study's Model 1). Although such a model treats ordinal rank scores as if they are continuous, it is difficult to reconstruct the underlying continuous measure (Freeman, 1987). Thus, the difference between ranks 1 and 2 may not actually be the same as the difference between ranks 2 and 3. Bolker *et al.* (2008) argued that the generalized mixed linear model approach is the most powerful and challenging procedure, combining the properties of linear mixed models and generalized linear models (which handle non-normally distributed data). Therefore, to solve the statistical problem, the generalized linear mixed model approach was adopted after converting the ordinal scores into three types of binary (1 or 0) scores (Models 2, 3 and 4) in the present study.

Effect of the priority of access to food on the carcass traits

The result showed that animals with higher priority of access to food tended to have heavier carcass weight than animals with lower priority of access to food. This result agreed with those of Bouissou *et al.* (2001) who showed that among cows that had free access to food, lower-social ranking cows ate less food and had smaller weight than higher-ranking cows. Phillips and Rind (2002) found that weight gain of the dominant cows increased more than subordinates in dairy cattle.

Surprisingly, there was a significant effect between the priority of access to food and the marbling score for Japanese Black cattle in this study. Nkrumah *et al.* (2007) reported that the daily feeding duration had a positive genetic correlation with the marbling score in beef cattle sired by Angus, Charolais or Hybrid bulls ($R = 0.56$), implying that animals that spent more time eating in a day generally had fatter carcasses with higher marbling. This might have been caused by the unavoidable circumstances, where higher-ranking animals could have gotten more favorable caloric concentrate preferentially. As there was no information on the feeding duration and feed intake of each animal in the present study, we could not ascertain the possibility that animals with higher priority of access to food ate a more nutritious fraction of the feed than animals with lower priority of access to food. Further research is required to elucidate this point.

Conclusions

The priority of access to food was influenced by age of animals in a pen and maternal grandsire line (i.e. genetic performance of dams), and it also tended to have an effect on carcass weight and had a significant effect on beef marbling for Japanese Black cattle under the production system of the present study. Although this study was the first report indicating the relationship between the priority of access to food and beef marbling, further research for other breeds and in other environments should be needed to assess and confirm the new findings. In addition, it should be noticed that the priority of access to food was determined by on-site direct observation by farmers, indicating that our method was quite different from ones in any other behavioral studies. However, the priority of access to food is relatively easy measurements to be ranked by farmers even under confined production circumstances, especially when the production size is comparatively small. To our knowledge, the present study was the first attempt to utilize such information on the analysis of the effect of social rank on the productive traits in beef cattle production systems. Although the present study used the records from only one representative farm in this region, the simple indicator (the ranking of access to food) of social rank can be collected easily from other farms in various regions. Hence, our study can emphasize the importance of the on-site information about the priority of access to food determined by farmers' own observation, and may indicate a new way for improving animal managements by analyzing the effects of the priority of access to food on animal performance in confined beef cattle production systems.

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References

Asada M, Hashiyada Y and Konishi K 2004. Effect of paternal line of donor on superovulatory response and embryo quality in Japanese Black heifers. Reproduction, Fertility and Development 16, 287–287.

Bolker BM, Brooks ME, Clark CJ, Geange SW, Poulsen JR, Stevens MHH and White JS 2008. Generalized linear mixed models: a practical guide for ecology and evolution. Trends in Ecology & Evolution 24, 127–135.

Bouissou MF, Boissy A, Le Neindre P and Veissier I 2001. The social behaviour of cattle. In Social Behaviour Farm Animals (ed. LJ Keeling and HW Gonyou), pp. 113–145. CABI Publishing, Wallingford, UK.

Dickson DP, Barr GR and Wieckert DA 1967. Social relationship of dairy cows in a feedlot. Behaviour 29, 195–203.

Dickson DP, Barr GR, Johnson LP and Wieckert DA 1970. Social dominance and temperament of Holstein cows. Journal of Dairy Science 53, 904–907.

Drews C 1993. The concept and definition of dominance in animal behaviour. Behaviour 125, 283–313.

Fordyce G, Fitzpatrick LA, Cooper NJ, Doogan VJ, De Faveri J and Holroyd RG 2002. Bull selection and use in northern Australia. V. Social behaviour and management. Animal Reproduction Science 71, 81–99.

Francis RC 1988. On the relationship between aggression and social dominance. Ethology 78, 223–237.

Freeman DH Jr 1987. Applied categorical data analysis. Marcel Dekker Inc., New York, USA.

Hafez ESE and Bouissou ME 1975. The behaviour of cattle. In The behaviour of domestic animals (ed. ESE Hafez), pp. 247–296. The Williams and Wllkins Co., Baltimore, MD.

Hart BL 1985. The behavior of domestic animals. WH Freeman and Company, New York, USA.

Hirooka H, Groen AF and Matsumoto M 1996. Genetic parameters for growth and carcass traits in Japanese brown cattle estimated from field records. Journal of Animal Science 74, 2112–2116.

Houpt KA 2011. Aggression and social structure. In Domestic animal behavior for veterinarians and animal scientists (ed. KA Houpt), pp. 416. Wiley-Blackwell, Ames, Iowa, USA.

Huzzey JM, Weary DM, Tiau BYF and von Keyserlingk MAG 2014. Short communication: automatic detection of social competition using an electronic feeding system. Journal of Dairy Science 97, 2953–2958.

Ikeda K and Fujii S 2006. The effects of bull strains and environment in the development of muscular abnormality in Japanese black cattle. Journal of the Japan Veterinary Medical Association 59, 623–625. in Japanese.

Japan Meat Grading Association 1989. Trading standards for carcass and retail cuts of beef and pork. Japan Meat Grading Association, Tokyo, Japan.

Landaeta-Hernández AJ, Rae DO, Kaske M and Archbald LF 2013. Factors influencing social organization in postpartum Angus cows under confinement. Effect on cow-calf weight change. Livestock Science 152, 47–52.

Landaeta-Hernández AJ, Chenoweth PJ, Tran T, Rae DO, Randles R and Chase CC Jr 2005. Estimating the dominance order in a mixed-breed herd: a practical methodology. Revista Científica FCV-LUZ XV, 148–154.

Langbein J and Puppe B 2004. Analysing dominance relationships by sociometric methods – a plea for a more standardised and precise approach in farm animals. Applied Animal Behaviour Science 87, 293–315.

Le Neindre P 1989. Influence of rearing conditions and breed on social behaviour and activity of cattle in novel environments. Applied Animal Behaviour Science 23, 129–140.

MacKay JRD, Turner SP, Hyslop J, Deag JM and Haskell MJ 2013. Short-term temperament tests in beef cattle relate to long-term measures of behavior recorded in the home pen. Journal of Animal Science 91, 4917–4924.

Maeno H, Oishi K, Mitsuhashi T, Kumagai H and Hirooka H 2014. Prediction of carcass composition and individual carcass cuts of Japanese Black steers. Meat Science 96, 1365–1370.

McPhee CP, McBride G and James JW 1964. Social behaviour of domestic animals. III. Steers in small yards. Animal Production 6, 9–15.

Miranda-de la Lama GC, Sepúlveda WS, Montaldo HH, María GA and Galindo F 2011. Social strategies associated with identity profiles in dairy goats. Applied Animal Behaviour Science 134, 48–55.

Miranda-de la Lama GC, Pinal R, Fuchs K, Montaldo H, Ducoing A and Galindo F 2013a. Environmental enrichment and social rank affects the fear and stress response to regular handling of dairy goats. Journal of Veterinary Behavior; Clinical Applications and Research 8, 342–348.

Miranda-de la Lama GC, Pascual-Alonso M, Guerrero A, Alberti P, Alierta S, Sans P, Gajan JP, Villarroel M, Dalmau A, Velarde A, Campo MM, Galindo F, Santolaria MP, Sañudo C and María GA 2013b. Influence of social dominance on production, welfare and the quality of meat from beef bulls. Meat Science 94, 432–437.

Nkrumah JD, Crews DH, Basarab JA, Price MA, Okine EK, Wang Z, Li C and Moore SS 2007. Genetic and phenotypic relationships of feeding behavior and temperament with performance, feed efficiency, ultrasound, and carcass merit of beef cattle. Journal of Animal Science 85, 2382–2390.

Partida JA, Olleta JL, Campo MM, Sañudo C and María GA 2007. Effect of social dominance on the meat quality of young Friesian bulls. Meat Science 76, 266–273.

Phillips CJC and Rind MI 2002. The effects of social dominance on the production and behavior of grazing dairy cows offered forage supplements. Journal of Dairy Science 85, 51–59.

SAS 2008. User's guide: statistics, version 9.2. SAS Institute Inc., Cary, NC, USA.

Solano J, Galindo F, Orihuela A and Galina CS 2004. The effect of social rank on the physiological response during repeated stressful handling in Zebu cattle (*Bos indicus*). Physiology & Behavior 82, 679–683.

Stricklin WR, Graves HB, Wilson LL and Singh RK 1980. Social organization among young beef cattle in confinement. Applied Animal Ethology 6, 211–219.

Val-Laillet D, de Passillé AM, Rushen J and von Keyserlingk MAG 2008. The concept of social dominance and the social distribution of feeding-related displacements between cows. Applied Animal Behaviour Science 111, 158–172.

Val-Laillet D, Guesdon V, Rushen J, von Keyserlingk MAG and de Passillé AM 2009. Allogrooming in cattle: relationships between social preferences, feeding displacements and social dominance. Applied Animal Behaviour Science 116, 141–149.