Published December 8, 2014

Genetic relationships between growth and carcass traits and profitability in Japanese Brown cattle[1]

A. K. Kahi,*†[2] T. Oguni,‡ Y. Sumio,‡ and H. Hirooka†

*Animal Breeding and Genetics Group, Department of Animal Sciences, Egerton University, PO Box 536, 20107 Njoro, Kenya; †Laboratory of Animal Husbandry Resources, Division of Applied Biosciences, Graduate School of Agriculture, Kyoto University, 606 8502 Kyoto, Japan; and ‡Kumamoto Agricultural Research Center, Kikuchi-gun, 861-1113 Kumamoto, Japan

ABSTRACT: The objectives of this study were 1) to examine the genetic relationship between growth and carcass traits and carcass price (CaP) and profitability in Japanese Brown cattle, 2) to estimate economic values of carcass and growth traits as regression coefficients of price and profit traits on growth and carcass traits using a multiple regression model, and 3) to compare direct and indirect predictions of the genetic merit of profit obtained from multitrait analysis and selection index, respectively. Growth and carcass traits considered in this study were ADG during the feedlot period, CWT, LM area (LMA), rib thickness (RT), subcutaneous fat thickness (SFT), and marbling score (MS). Carcass price was evaluated as a price trait independent of its influence on profit. Profit traits were defined as 1) net income per year (PROF1), 2) net income per year/energy requirement (PROF2), and 3) net income per year minus feed costs (PROF3). Correlations between direct and indirect predictions were estimated based on EBV of sires and dams with progeny records. The heritability estimate for CaP was 0.41. The heritability estimates for profit traits were high and were 0.62, 0.66, and 0.60 for PROF1, PROF2, and PROF3, respectively. The genetic correlations between CaP and ADG, CWT, LMA, RT, SFT, and MS were 0.19, 0.14, 0.30, 0.38, –0.11, and 0.98, respectively. Among the profit traits, PROF1 had the greatest genetic correlations with growth and carcass traits. The correlations with ADG, CWT, LMA, RT, SFT, and MS were 0.30, 0.21, 0.24, 0.39, –0.01, and 0.69, respectively. These estimates indicate that use of profit traits as a selection criterion may promote desirable correlated responses in growth and carcass traits. The economic values for growth and carcass traits estimated relative to CaP and each profit trait differed because of the apparent differences in the description of these traits. The correlations between EBV for the same profit traits from direct and indirect predictions were high and ranged from 0.818 to 0.846 based on EBV of sires and from 0.786 to 0.798 based on EBV of dams. The strong correlations between direct and indirect predictions for profit indicate that there is no advantage to selecting directly for profit compared with an index with all of the component traits.

Key words: beef cattle, carcass trait, economic value, Japanese Brown cattle, profit

J. Anim. Sci. 2007. 85:348–355
doi:10.2527/jas.2005-657

INTRODUCTION

In beef cattle breeding, the genetic merit of breeding cattle for the profitability of their progeny can be predicted using 2 approaches. Firstly, economic values can be used to combine predicted breeding values of individual traits into an overall EBV for economic merit. This approach (indirect prediction) takes into account the differences in genetic parameters between traits in the breeding objective. Secondly, several components of the breeding objective can be combined into 1 trait, profit. The profitability for individual cattle can be calculated and used to estimate EBV for profit directly. This approach (direct prediction) ignores the differences in genetic parameters between components of profit but compensates for this loss in efficiency by the advantages of direct analysis of profit (Visscher and Goddard, 1995).

In dairy cattle, several studies have directly analyzed profitability and determined its relationships with other traits of economic importance and its suitability

[1]We thank Kyoto University, Kyoto, Japan, for provision of facilities and the Japan Society for the Promotion of Science (JSPS) for funding this study. This paper was written when A. K. Kahi was at the Laboratory of Animal Husbandry Resources, Division of Applied Biosciences, Graduate School of Agriculture, Kyoto University, Japan.

[2]Corresponding author: a.kahi@incip.org

Received November 11, 2005.
Accepted September 5, 2006.

as a direct predictor of genetic merit (Visscher and Goddard, 1995; Pérez-Cabal and Alenda, 2002). For beef cattle, little is known about the relationship between profitability and growth and carcass traits; however, the relationship with type traits has been reported (Forabosco et al., 2005).

The objectives of this study were to examine the genetic relationship between growth and carcass traits and carcass price (**CaP**) and profitability in Japanese Brown cattle, to estimate economic values of carcass and growth traits as regression coefficients (positive approach) of price and profit traits on growth and carcass traits using a multiple regression model and to compare direct and indirect predictions of the genetic merit of profit obtained from multitrait analysis and selection index, respectively.

MATERIALS AND METHODS

Animal Care and Use Committee approval was not obtained for this study because the data were obtained from an existing database at the Kumamoto Agricultural Research Center.

Data and Definition of Traits

Data on growth and carcass traits and prices were collected from 8,099 Japanese Brown cattle sold in 9 carcass markets in Kumamoto prefecture from January 1998 to December 2000. These cattle were the progeny of 88 sires and 6,658 dams and were born in different herds within the Kumamoto prefecture. The average number of progeny per sire was 92. The cattle were purchased by feedlot farmers at calf markets at an average age and initial BW (**IWT**) of 290 d and 293 kg, respectively. The average calf price (**CCALF**) was ¥281,187.

The cattle were raised under feedlot management systems. The size of the feedlot operation was small, fewer than 5 cattle in some cases. In Japan, feedlot management, and especially the feeding regimen, is almost homogenous (Sasaki, 2001). Cattle in this study were given free access to concentrates for ad libitum intake and restricted access to roughage, mainly rice straw. Concentrates mainly consisted of ground barley, ground yellow corn, and wheat bran. On an as-fed basis, the proportions of concentrate and roughage were approximately 85:15. The average length of the feedlot period (**LFP**) in this study was 470 d, whereas the average slaughter age and BW were 761 d and 667 kg, respectively.

Four groups of traits were considered in this study, namely growth, carcass, price, and profit traits. The ADG during the feedlot period was the only growth trait, whereas carcass traits included CWT, LM area (**LMA**), rib thickness (**RT**), subcutaneous fat thickness (**SFT**), and marbling score (**MS**). Measurements of LMA, RT, SFT, and MS were at the sixth-seventh rib section (Sasaki, 2001). The LMA was measured by grid approximation on the left side of the carcass. The RT was the distance between the latissimus muscle and pleural membrane measured halfway between the rib ends. The MS was measured according to the Beef Marbling Standards with scores of 1 to 12, with number 12 being the best (JMGA, 1988).

Evaluating the genetic components of price is an important step in understanding the inheritance of profit. Therefore, in this study CaP was evaluated as a price trait independent of its influence on profit. Three profit traits of interest were analyzed. These traits differed in the way profit was determined. Profit was defined as 1) net income (**PROF1**), 2) net income/energy requirement (**PROF2**), and 3) net income minus feed costs (**PROF3**). The net income per year per animal (PROF1) was defined as the difference between the carcass value and CCALF and was calculated as follows:

$$\text{PROF1} = [(\text{CWT} \times \text{CaP}) - \text{CCALF}] \times \frac{365}{\text{LFP}}. \quad [1]$$

The CCALF represents both the value and cost of animal entering the feeding period. The PROF2 was obtained as the ratio of PROF1 to the total ME requirement per year (**TME**) for Japanese Brown feedlot cattle, with TME (in MJ) simulated as follows:

$$\text{TME} = \frac{365}{\text{LFP}} \sum_{i=1}^{\text{LFP}} (\text{ME}_m + \text{ME}_g)_i, \quad [2]$$

where ME_m and ME_g are the daily ME requirement (MJ/d) for maintenance and growth, respectively, calculated based on MAFF (2000), as follows:

$$\text{ME}_m = 0.1124\text{WT}^{0.75} \times 4.184, \text{ and} \quad [3]$$

$$\text{ME}_g = \frac{[0.0546\text{WT}^{0.75} \times (\text{ADG}/1000)] \times 4.184}{0.78q + 0.006} \times (1.653 - 0.00123\text{WT}), \quad [4]$$

where WT = BW on day i during the feedlot period, in kg, and was determined assuming linear growth based on IWT and ADG (i.e., WT = IWT + [i × (ADG/1,000)] and q = 0.5304 + (0.0748ADG/1,000) (MAFF, 2000). The PROF3 was obtained as PROF1 minus feed costs and was calculated as follows:

$$\text{PROF3} = \text{PROF1} - \left\{[(\text{TME} \times 0.85 \times \text{PC}) + (\text{TME} \times 0.15 \times \text{PR})] \times \frac{365}{\text{LFP}}\right\}, \quad [5]$$

where PC = price (in ¥) of concentrates per MJ of ME, PR = price (in ¥) of roughage per MJ of ME, and the ratios 0.85 and 0.15 represent the respective proportions of concentrates and roughages on an as-fed basis. Price of roughage is generally greater than that of con-

Table 1. Number of cattle with records, means, SD, and CV of growth, carcass, price, and profit traits

Trait[1]	No. of records	Means	SD	CV, %
ADG, g/d	8,099	908.64	144.48	16
CWT, kg	8,099	429.96	45.51	11
LMA, cm^2	8,099	48.37	5.67	12
RT, cm	8,098	7.04	0.74	11
SFT, cm	8,099	2.59	0.85	33
MS, score	8,098	3.05	1.09	36
CaP, ¥/kg	8,045	1,226.54	270.20	22
PROF1, ¥/100	8,045	2,124.17	1,177.42	55
PROF2, ¥ × 100	8,045	601.15	321.14	53
PROF3, ¥/100	8,045	598.65	1,142.80	191

[1]ADG = Average daily gain during the feedlot period; LMA = LM area; RT = rib thickness; SFT = subcutaneous fat thickness; MS = marbling score; CaP = carcass price; PROF1 = net income per year; PROF2 = net income per year/energy requirement; and PROF3 = net income per year minus feed costs.

centrates in Japan (MAFF, 2000). The PC and PR were ¥4.10 and 5.33 per MJ of ME, respectively.

In any livestock production enterprise, there is a distinction between feed and nonfeed costs. Nonfeed costs include fixed costs (housing, machines, and building and equipment repair) and other variable costs; e.g., labor costs, veterinary costs and marketing costs. It was not possible to estimate these nonfeed costs from the data used in this study. However, by including feed costs, a large proportion of the costs was accounted for because feed costs are major determinants of profitability in most commercial beef production enterprises (Montaño-Bermudez et al., 1990; Parnell et al., 1994; Arthur et al., 2001). Table 1 shows the number of cattle with records, means, and SD of growth, carcass, price, and profit traits.

Estimation of Genetic Parameters

Genetic parameters and EBV for all traits were estimated by the REML method using the multiple-trait, derivative-free REML programs (Boldman et al., 1993). Convergence was assumed when the variance of the –2 log likelihood in the simplex was less than 10^{-8}. Data were analyzed using series of bivariate animal models with one of the price or profit traits included as one of the traits. The model used in this analysis was:

$$Y_{ijklm} = \mu + YM_i + M_j + S_k + a_1 + b_1A_{ijklm} + b_2A_{ijklm} + b_3LFP_{ijklm} + b_4LFP_{ijklm} + e_{ijklm}, \quad [6]$$

where Y_{ijklm} is observation ijklm for the trait, μ is the population mean, YM_i is the fixed effect of slaughter year and month i (1 to 36), M_j is the fixed effect of market j (1 to 9), S_k is the fixed effect of sex k (1 to 2), a_l is the random effect of animal 1, b_1 and b_3 are linear partial regression coefficients, b_2 and b_4 are quadratic partial regression coefficients, A_{ijklm} is the slaughter age in days, LFP_{ijklm} is the length of the feedlot period in days, and e_{ijklm} is the random residual associated with observation ijklm. In the analysis of PROF1, PROF2, and PROF3, length of the feedlot period was not fitted as a covariate. The series of bivariate analyses resulted in more than one estimate of heritability for all traits. These estimates were pooled, weighting each estimate by the inverse of its sampling variance (Maiwashe et al., 2002).

Estimation of Economic Values

An aggregate genotype (**H**) is a linear function of breeding values (**EBVi**) of the trait i multiplied by the relative economic value ($\mathbf{v_i}$; Wilton, 1982). However, when defined based on a phenotypic observation (**P**) instead of H, the phenotypic value ($\mathbf{X_i}$) could be a good approximation of the EBV_i (Harris, 1970). Using multiple regression analysis, H and P can be regressed on EBV_i and X_i, respectively, to obtain v_i, a 1-unit change in the breeding value considering all other traits unchanged. Economic values of growth and carcass traits were estimated as regression coefficients of price and profit traits (dependent variables) on growth and carcass traits (independent variables) using PROC REG of SAS (SAS Inst. Inc., Cary, NC). Economic values were estimated based on the EBV of sires or dams with progeny records, EBV of slaughtered individuals, and EBV of all cattle in the data.

Comparison of Direct and Indirect Predictors of the Genetic Merit for Profit

Two predictions of the genetic merit of breeding cattle for profitability of their progeny were compared. The first was the direct prediction of genetic merit for profit using multitrait analysis. Here, profit is regarded as a single trait, and breeding cattle are ranked based on EBV for price and profit traits. The second was an indirect prediction, where the EBV of growth and carcass traits are weighted in a selection index by their respective economic values to calculate an aggregate genotype. In this case, the breeding cattle are ranked based on the calculated aggregate genotype comprising the EBV and economic values for ADG, CWT, LMA, RT, SFT, and MS. The correlations between EBV for price and profit traits from direct predictions and aggregate genotype from indirect prediction were estimated using PROC CORR of SAS (SAS Inst. Inc., Cary, NC).

RESULTS AND DISCUSSION

Means, SD, and Coefficients of Variation of Growth, Carcass, Price, and Profit Traits

Growth, carcass, price and profit traits means, SD, and CV are shown in Table 1. During the feedlot period, the average daily gain was 908.64 g/d and the average CWT was 429.96 kg. The average LMA, RT, SFT, and MS were 48.37 cm^2, 7.04 cm, 2.59 cm, and 3.05, respec-

Table 2. Additive variance and heritability for growth, carcass, price, and profit traits

	Additive variance[2]			
Trait[1]	Mean	Minimum	Maximum	Heritability
ADG, g/d	508.94	501.54	512.77	0.39
CWT, kg	764.34	762.12	767.75	0.45
LMA, cm^2	7.97	7.89	8.06	0.29
RT, cm	0.22	0.22	0.22	0.32
SFT, cm	0.49	0.49	0.49	0.58
MS, score	0.62	0.61	0.63	0.52
CaP, ¥/kg	281.90	277.98	294.03	0.41
PROF1, ¥/100	8,848.78	8,679.35	9,002.89	0.62
PROF2, ¥ × 100	720.85	709.49	730.39	0.66
PROF3, ¥/100	8,600.77	8,454.76	8,734.08	0.60

[1]ADG = ADG during the feedlot period; LMA = LM area; RT = rib thickness; SFT = subcutaneous fat thickness; MS = marbling score; CaP = carcass price; PROF1 = net income per year; PROF2 = net income per year/energy requirement; and PROF3 = net income per year minus feed costs.
[2]Mean and range from different bivariate analyses.

tively. The average CaP per kilogram was ¥1,227, whereas the average net income per year was ¥212,417 (**PROF1**) and ¥6.01 (**PROF2**) when expressed per unit of total ME requirement per year. Inclusion of feed costs resulted in a profitability of ¥59,865 (**PROF3**). The difference between PROF1 and PROF3 (¥152,552) emphasizes the importance of feed costs in determining the profitability of beef production enterprises (Hoque et al., 2006). The SD and coefficient of variation for PROF3 were high.

Heritability and Genetic Correlations

The additive genetic variances and heritability for growth, carcass, price, and profit traits are presented in Table 2. The minimum and maximum values for the series of bivariate analyses indicate that for a particular trait, the additive variances were relatively stable from one analysis to the other. The heritability estimate for ADG was 0.39 (Table 2) and was greater than literature reports in the Japanese Brown (Sasaki, 1991; Hirooka et al., 1996). Estimated heritability for CWT (0.45) corresponds with estimates by Ibi et al. (2005) for Japanese Black steers but greater than the estimates of 0.14 by Fukuhara et al. (1989) and 0.39 by Mukai et al. (1995) from Japanese Black steers. The estimate of heritability for CWT was lower than the estimate of 0.64 reported by Kawada et al. (2003). Estimated heritability for LMA (0.29) was within the range (0.28 to 0.46) in the literature (Arnold et al., 1991; Hirooka et al., 1996; Ibi et al., 2005). The heritability estimate of 0.32 for RT is similar to estimates by Ibi et al. (2005) but greater than the estimates of 0.23 and 0.26 reported by Fukuhara et al. (1989) and Hirooka et al. (1996). Estimated heritability for SFT (0.58) was within the literature range (0.26 to 0.68; Marshall, 1994). However, lower estimates of heritability for SFT were reported for different Japanese beef breeds (Fukuhara et al., 1989; Mukai et al., 1995; Ibi et al., 2005). The estimate of heritability for MS (0.52) was similar to literature values for Japanese Black cattle (Mukai et al., 1995; Oikawa et al., 2000; Kawada et al., 2003). A lower average estimate (0.35) was reported in a literature summary by Marshall (1994).

The heritability estimate for CaP was 0.41 and similar to the value of 0.49 reported by Hirooka and Matsumoto (1996) in the Japanese Brown cattle and within the range of 0.32 to 0.46 reported by Ibi et al. (2006) in the Japanese Black cattle. In those studies, CaP was also considered as a price trait. The heritability estimates for profit traits were high and were 0.62, 0.66 and 0.60 for PROF1, PROF2, and PROF3, respectively. The profit traits had a greater heritability than growth, carcass, and price traits that contributed to profit. Elsewhere, Forabosco et al. (2005) reported lower heritability estimates of 0.29 for yearly profit per cow in Chianina beef cows. That study, however, did not include information on sale prices, and therefore information on variability due to genetic difference in carcass yield and quality could not be calculated.

The genetic correlations between growth and carcass traits and price and profit traits are shown in Table 3. For most traits (apart from MS), the genetic correlation estimates with PROF1 were the greatest. Marbling score was the trait most strongly genetically correlated to CaP and all profits traits, followed by RT. Ibi et al. (2006) obtained similar results in the Japanese Black cattle. The greatest genetic correlation (0.98) between CaP and MS was expected because marbling is the most important trait in Japan because carcass value is primarily determined by the degree of marbling (Hirooka and Groen, 1999). Genetic correlation between profit traits and CaP and ADG, CWT, LMA, and RT were positive. This could be a consequence of the positive relationship between MS and these traits (Mukai et al., 1995; Hirooka et al., 1996; Kawada et al., 2003). Similarly, the genetic correlation between profit traits and CaP and SFT was a result of the negative relationship with MS estimated for indigenous Japanese beef cattle (Fukuhara et al., 1989; Mukai et al., 1995; Hirooka et al., 1996; Kawada et al., 2003).

Table 3. Genetic correlations between growth and carcass traits and price and profit traits

Growth and carcass trait[1]	CaP	Price and profit trait[2] PROF1	PROF2	PROF3
ADG	0.19	0.30	0.20	0.23
CWT	0.14	0.21	0.11	0.14
LMA	0.30	0.24	0.20	0.21
RT	0.38	0.39	0.33	0.34
SFT	–0.11	–0.01	–0.03	–0.04
MS	0.98	0.69	0.69	0.69

[1]ADG = ADG during the feedlot period; CWT = carcass weight; LMA = LM area; RT = rib thickness; SFT = subcutaneous fat thickness; and MS = marbling score.

[2]CaP = Carcass price; PROF1 = net income per year; PROF2 = net income per year/energy requirement; and PROF3 = net income per year minus feed costs.

For most traits, the genetic correlation estimates with PROF2 were the lowest, but the difference between these estimates and those with PROF3 were small. The PROF2 relates to a ratio, whereas PROF3 relates to the actual profitability because it is the difference between income and feed costs; actual feed intakes were not known but predicted as a function of ADG and weight. This study showed that the method of combining net income and feed intake (whether as differences between income and feed costs or ratio of income to total ME requirement per year) has little effect on the estimate of genetic correlations with growth and carcass traits. This implies that selection based on PROF2 or PROF3 will result in similar genetic response in growth and carcass traits. This has important consequences because it means that even in the absence of actual costs of feeds (concentrates and roughages), which is difficult to obtain in some production systems, the genetic merit of breeding cattle for profitability can still be predicted using total ME requirement estimated using standard feeding equations.

Economic Values

Table 4 shows the economic values for growth and carcass traits estimated using multiple regressions. The economic values for growth and carcass traits estimated relative to price and each profit trait differed. This difference is apparent because of the differences in the description of dependent variables. The economic values estimated relative to PROF1 and PROF3 differ because of inclusion of feed costs and were lower when estimated based on PROF3 for traits that were directly related to feed costs (e.g., ADG). Economic values for MS based on PROF3 were greater than when based on PROF1 because MS was not directly related to feed costs. The economic values for growth and carcass traits derived based on PROF1 and PROF2 differ by a factor that is equal to the total metabolizable energy requirement per year. The economic values derived based on PROF1 correspond to a situation with constant feed intake among the cattle in the herd, whereas economic values derived based on PROF2 and PROF3 correspond to a situation with no differences in efficiency of feed utilization between cattle (Kahi et al., 1998). The economic values for growth and carcass traits derived based on CaP had the lowest magnitude but showed similar trend to those obtained based on profit traits.

The economic values for growth and carcass traits estimated based on the EBV of sires and dams with progeny, EBV of slaughtered individuals, and EBV of all cattle differed within each profit trait. For example, relative to PROF1, the economic values for LMA were ¥–2,468, 49, –753, and 271 based on EBV of sires, dams, slaughtered individuals, and all cattle, respectively. In all cases, the greatest economic value was found for MS, consistent with other studies in Japan (Hirooka and Matsumoto, 1996; Hirooka and Sasaki, 1998; Ibi et al., 2006). The economic values for ADG, RT, and MS were positive in all cases, consistent with Hirooka and Matsumoto (1996). The economic values for ADG, RT, and MS were greatest when estimated based on EBV of slaughtered individuals. This reflects the importance of these traits in determining the profitability per slaughtered individual. The economic values for SFT estimated based on EBV of sire and slaughtered individuals were negative. Hirooka and Sasaki (1998) also reported a negative economic value for SFT when estimated based on CaP. Positive economic values for SFT are undesirable because animals with thicker subcutaneous fat may have heavier carcasses, which mistakenly would translate to greater profitability.

This study used actual profitability to estimate economic values for growth and carcass traits. The input variables included were CCALF and feed costs, which were simulated using feed requirement equations. Economic values are usually estimated either based on profit (i.e., income minus cost) or economic efficiency (income/costs or cost/income; Harris, 1970; James, 1982; Brascamp et al., 1985). Hirooka and Sasaki (1998) justified the use of breeding objectives utilizing economic values estimated based on CaP. This is only possible in situations where carcass prices can accurately be determined, as in Japan for example. However, inclusion of relevant information on input variables will result in more accurate economic values that will lead to more accurate indirect predictions of genetic merit. The expected response to selection in traits of interest has been shown to be influenced by the magnitude of economic values (Hirooka and Groen, 1999; Kahi et al., 2003; Wood et al., 2004).

Direct and Indirect Predictions of the Genetic Merit

Table 5 shows correlation coefficients between EBV for price and profit traits from direct predictions and aggregate genotype from indirect prediction based on the EBV of sires and dams with progeny records. The correlations between direct predictions of profit traits

Table 4. Economic values of growth and carcass traits estimated relative to price and profit traits and based on the EBV of sires (sire) and dams (dam) with progeny records, EBV of slaughtered individuals (slaughtered), and EBV of all cattle in the data (total)

Growth and carcass trait[1]	EBV	Price and profit trait[2]			
		CaP, ¥	PROF1, ¥/100	PROF2, ¥ × 100	PROF3, ¥/100
ADG, g/d	Sire	0.04	2.70	0.49	2.18
	Dam	0.12	5.46	1.17	4.57
	Slaughtered	0.16	5.78	1.33	4.98
	Total	0.07	4.58	0.93	3.68
CWT, kg	Sire	0.15	2.00	–0.09	0.36
	Dam	–0.07	–8.89	–2.92	–9.79
	Slaughtered	–0.26	–9.71	–3.22	–10.69
	Total	0.31	–4.33	–1.64	–5.25
LMA, cm^2	Sire	–1.00	–24.68	–6.94	–24.27
	Dam	–0.51	0.49	–0.75	–1.30
	Slaughtered	–0.47	–7.53	–2.68	–9.28
	Total	–0.15	2.71	0.55	1.91
RT, cm	Sire	26.37	204.97	68.47	214.66
	Dam	28.10	239.16	60.38	218.05
	Slaughtered	44.54	313.21	86.00	297.23
	Total	9.14	20.93	1.88	10.83
SFT, cm	Sire	–1.51	–91.34	–18.07	–85.28
	Dam	–8.19	–6.49	4.84	0.23
	Slaughtered	–8.93	–30.77	–3.17	–24.55
	Total	–1.48	17.81	11.20	24.66
MS, score	Sire	169.81	522.03	154.00	525.32
	Dam	181.14	622.01	196.53	652.99
	Slaughtered	183.08	671.31	214.92	706.01
	Total	103.24	586.98	180.90	609.18

[1]ADG = ADG during the feedlot period; LMA = LM area; RT = rib thickness; SFT = subcutaneous fat thickness; and MS = marbling score.

[2]CaP = Carcass price; PROF1 = net income per year; PROF2 = net income per year/energy requirement; and PROF3 = net income per year minus feed costs.

estimated based on both EBV of sires and dams were high (>0.995). The correlations between indirect predictions were also high (<0.990). This indicates that selection based on PROF1, PROF2, or PROF3 will provide almost the same results. The correlations between EBV from direct and indirect predictions of CaP and direct prediction of profits traits (ranged from 0.760 to 0.805) were lower than between EBV from direct and indirect predictions of CaP and indirect predictions of profit traits (ranged from 0.905 to 0.983). This suggests that direct selection for CaP would produce a response similar to indirect selection for profitability in Japanese Brown cattle. The correlations between EBV for same profit traits and CaP from direct and indirect predictions were high and ranged from 0.818 to 0.965 and from 0.786 to 0.959 based on EBV of sires and dams, respectively. These values are consistent with those estimated by Ibi et al. (2006) for the Japanese Black cattle. Lower correlations (ranging from 0.46 to 0.49) between direct and indirect predictions for lifetime

Table 5. Correlations between EBV for price and profit traits[1] from direct (subscript d) predictions and aggregate genotype from indirect (subscript in) predictions based on the EBV of sires (below diagonal) and dams (above diagonal) with progeny records

	CaP_d	$PROF1_d$	$PROF2_d$	$PROF3_d$	CaP_{in}	$PROF1_{in}$	$PROF2_{in}$	$PROF3_{in}$
CaP_d		0.779	0.805	0.780	0.959	0.905	0.919	0.916
$PROF1_d$	0.777		0.989	0.997	0.745	0.798	0.804	0.802
$PROF2_d$	0.760	0.989		0.995	0.725	0.762	0.786	0.776
$PROF3_d$	0.778	0.997	0.996		0.737	0.780	0.797	0.791
CaP_{in}	0.965	0.774	0.790	0.771		0.960	0.983	0.976
$PROF1_{in}$	0.910	0.846	0.806	0.824	0.962		0.989	0.995
$PROF2_{in}$	0.933	0.841	0.818	0.829	0.975	0.990		0.998
$PROF3_{in}$	0.926	0.845	0.815	0.829	0.973	0.996	0.998	

[1]CaP = Carcass price; PROF1 = net income per year; PROF2 = net income per year/energy requirement; and PROF3 = net income per year minus feed costs.

profits have been reported in dairy cattle (Pérez-Cabal and Alenda, 2003).

This study has shown that under the current consumer demand for marbled beef in Japan, selection based on direct or indirect predictions will provide the same results. This means that instead of determining an EBV for profit, an index with all of the traits that contribute to profit is still useful in determining the genetic merit of breeding cattle for profitability of their progeny. Selection on a trait that is a linear combination of other traits will not lead to greater response (Kennedy et al., 1993). The use of EBV for profit requires accurate data on input variables, which are usually difficult to obtain in most production systems. However, several reasons have been advanced in the literature to support the use of direct profit in genetic evaluation of cattle. When profit is considered as a trait, fewer genetic parameters (heritabilities) are needed than when dealing with selection indices (Visscher and Goddard, 1995; Meuwissen and Goddard, 1997). In addition, when complicated and nonlinear relationships between traits exist, direct selection for profit as a trait is recommended (Goddard, 1998). A question yet to be answered is whether the beef industry in Japan would be served better by use of accurate EBV of MS instead of direct profit given its high genetic correlations with profit traits and CaP (Table 3). The other carcass traits are also important in determining the genetic merit of breeding cattle because they are genetically correlated to MS and also determine the final carcass sale price. The carcass sale price is important to the farmers because a greater price of carcass means more income for them. Selection based on EBV of MS alone would therefore be a less optimal alternative.

Usually breeding objectives are dictated by the consumer demand for products and are therefore dynamic. Currently, consumer demand for marbled beef is high, but this could change in future in response to the effects of animal fat on health. Consequently, the demand for marbled beef will be low and the economic value of MS will be zero or even negative. In this case, selection may be based on biological breeding objectives. Fowler et al. (1976) and Maijala (1976) proposed the use of biological efficiency as a breeding objective because economic breeding objectives depend on economic conditions, which are usually unstable. When biological efficiency estimated as the ratio of weight gained during the feedlot period to TME (kg/MJ) was defined as a breeding objective, the correlation coefficients between EBV for profit traits and biological efficiency ranged from 0.517 to 0.704 and 0.276 to 0.484 for EBV of sires and dams, respectively. However, when biological breeding objectives are used, it is difficult to monitor changes in components and update them (Ponzoni and Davis, 1989). Nonetheless, there is the need for genetic flexibility and development of strains with divergent biological characteristics as a supplement to existing improvement methods (Land, 1981). This is important given the biological diversification of beef cattle breeding in Japan.

IMPLICATIONS

The genetic correlation between profit and growth and carcass traits were favorable, indicating that use of profit traits as a selection criterion may promote desirable correlated response in growth and carcass traits and, consequently, could contribute to increased profitability in the production enterprise. The strong correlations between direct and indirect predictions for profit indicate that there is no advantage to directly selecting for profit compared with an index with all of the component traits. For Japan, where carcass unit price and carcass sale price are accurately and routinely recorded, use of estimated breeding value for profit traits in determining the genetic merit of breeding cattle for profitability of their progeny is an alternative. However, the current definition of profit traits did not include traits expressed in sires and cows, and so when making selection decisions, estimated breeding value for such traits would still need to be combined with estimated breeding value for profit traits.

LITERATURE CITED

Arnold, J. W., J. K. Bertrand, L. L. Benyshek, and C. Ludwig. 1991. Estimates of genetic parameters for live animal ultrasound, actual carcass data and growth traits in beef cattle. J. Anim. Sci. 69:985–992.

Arthur, P. F., J. A. Archer, D. J. Johnston, R. M. Herd, E. C. Richardson, and P. F. Parnell. 2001. Genetic and phenotypic variance and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle. J. Anim. Sci. 79:2805–2811.

Boldman, G., L. A. Kriese, L. D. Van Vleck, and S. D. Kachman. 1993. A manual for use of MTDFREML. A set of programs to obtain estimates of variances and covariances [Draft]. USDA-ARS, Clay Center, NE.

Brascamp, E. W., C. Smith, and D. R. Guy. 1985. Derivation of economic weights from profit equations. Anim. Prod. 40:175–180.

Forabosco, F., R. Bozzi, P. Boettcher, F. Filippini, P. Bijma, and J. A. M. van Arendonk. 2005. Relationship between profitability and type traits and derivation of economic values for reproduction and survival traits in Chianina beef cows. J. Anim. Sci. 83:2043–2051.

Fowler, V. R., M. Bichard, and A. Pease. 1976. Objectives in pig breeding. Anim. Prod. 23:365–389.

Fukuhara, R., K. Moriya, and H. Harada. 1989. Estimation of genetic parameters and sire evaluation for carcass characteristics with special reference to yield grade of the new beef carcass grading standards. Jpn. J. Zootech. Sci. 60:1128–1132.

Goddard, M. E. 1998. Consensus and debate in the definition of breeding objectives. J. Dairy Sci. 81:6–18.

Harris, D. L. 1970. Breeding for efficiency in livestock production: Defining the economic objectives. J. Anim. Sci. 30:860–865.

Hirooka, H., and A. F. Groen. 1999. Effects of production circumstances on expected responses for growth and carcass traits to selection of bulls in Japan. J. Anim. Sci. 77:1135–1143.

Hirooka, H., A. F. Groen, and M. Matsumoto. 1996. Genetic parameters for growth and carcass traits in Japanese Brown cattle estimated from field records. J. Anim. Sci. 74:2112–2116.

Hirooka, H., and M. Matsumoto. 1996. A comparison of selection approaches for Japanese Brown cattle based on profitability. Nihon Chikusan Gakkaiho. 67:886–892.

Hirooka, H., and Y. Sasaki. 1998. Derivation of economic weights for carcass traits in Japanese Black cattle from field records. J. Anim. Breed. Genet. 115:27–37.

Hoque, M. A., P. F. Arthur, K. Hiramoto, and T. Oikawa. 2006. Genetic relationship between different measures of feed efficiency and its components traits in Japanese Black (Wagyu) bulls. Livest. Sci. 99:111–118.

Ibi, T., H. Hirooka, A. K. Kahi, Y. Sasae, and Y. Sasaki. 2005. Genotype × environment interaction effects on carcass traits in Japanese Black cattle. J. Anim. Sci. 83:1503–1510.

Ibi, T., A. K. Kahi, and H. Hirooka. 2006. Economic effect on genetic and economic evaluation of carcass traits in Japanese Black cattle. J. Anim. Sci. 84:3204–3211.

James, J. W. 1982. Economic aspects of developing breeding objectives: General considerations. Pages 107–118 in J. S. F. Barker, K. Hammond, and A. E. McClintock, ed., Future Development in the Genetic Improvement of Animals. Academic Press, Bowen Hills, Australia.

JMGA (Japan Meat Grading Association). 1988. New Beef Grading Standards [in Japanese]. Japanese Meat Grading Associations, Tokyo.

Kahi, A. K., S. A. Barwick, and H.-U. Graser. 2003. Economic evaluation of Hereford cattle breeding schemes incorporating direct and indirect measures of feed intake. Aust. J. Agric. Res. 54:1039–1055.

Kahi, A. K., I. S. Kosgey, V. L. Cardoso, and J. A. M. Van Arendonk. 1998. Influence of production circumstance and economic evaluation criteria on economic comparison of breeds and breed crosses. J. Dairy Sci. 81:2271–2279.

Kawada, K., S. Kanematsu, Y. Kurosawa, T. Ibi, and Y. Sasaki. 2003. Genetic statistical analysis on carcass traits and daily gain of Japanese Black cattle in southern part of Iwate Prefecture Nihon Chikusan Gakkaiho 74:187–193.

Kennedy, B. W., J. H. J. van der Werf, and T. H. E. Meuwissen. 1993. Genetic and statistical properties of residual feed intake. J. Anim. Sci. 71:3239–3250.

Land, R. B. 1981. An alternative philosophy for livestock breeding. Livest. Prod. Sci. 8:95–99.

MAFF (Ministry of Agricultural. Fisheries and Food). 2000. Japanese Feeding Standard for Beef Cattle. Agriculture, Forestry and Fisheries Research Council Secretariat. Japan Livestock Industry Association, Tokyo.

Maijala, K. 1976. General aspects in defining breeding goals in farm animals. Acta Agric. Scand. 26:40–46.

Maiwashe, A. N., M. J. Bradfield, H. E. Theron, and J. B. van Wyk. 2002. Genetic parameter estimates for body measurements and growth traits in South African Bonsmara cattle. Livest. Prod. Sci. 75:293–300.

Marshall, D. M. 1994. Breed differences and genetic parameters for body composition traits in beef cattle. J. Anim. Sci. 72:2745–2755.

Meuwissen, T. H. E., and M. E. Goddard. 1997. Selection of farm animals for non-linear traits and profit. Anim. Sci. 65:1–8.

Montaño-Bermudez, M., M. K. Nielsen, and G. H. Deutscher. 1990. Energy requirements for maintenance of crossbred beef cattle with different genetic potential for milk. J. Anim. Sci. 68:2279–2288.

Mukai, F., K. Oyama, and S. Kohno. 1995. Genetic relationship between performance test traits and field carcass traits in Japanese Black cattle. Livest. Prod. Sci. 44:199–205.

Oikawa, T., T. Sanehira, K. Sato, Y. Mizuguchi, H. Yamamoto, and M. Baba. 2000. Genetic parameters for growth and carcass traits of Japanese Black (Wagyu) cattle. Anim. Sci. 71:59–64.

Parnell, P. F., R. M. Herd, D. Perry, and B. Bootle. 1994. The Trangie experiment- Response in growth rate, size, maternal ability, reproductive performance, carcases composition, feed requirements and herd profitability. Proc. Aust. Soc. Anim. Prod. 20:17–26.

Pérez-Cabal, M. A., and R. Alenda. 2002. Genetic relationships between lifetime profit and type traits in Spanish Holstein cows. J. Dairy Sci. 85:3480–3491.

Pérez-Cabal, M. A., and R. Alenda. 2003. Lifetime profit as an individual trait and prediction of its breeding values in Spanish Holstein cows. J. Dairy Sci. 86:4115–4122.

Ponzoni, R. W., and R. L. Davis. 1989. An evaluation of biological and conventional pig selection indices. Aust. J. Exp. Agric. 29:775–779.

Sasaki, Y. 1991. Sire evaluation systems for beef cattle [in Japanese]. Page 117 in Kyoto School on breeding and improvement for beef cattle. Kyoto University, Kyoto, Japan.

Sasaki, Y. 2001. Beef cattle breeding and its trend in Japan. Asian-Aust. J. Anim. Sci. 14:111–122.

Visscher, P. M., and M. E. Goddard. 1995. Genetic analyses of profit for Australian dairy cattle. Anim. Sci. 61:9–18.

Wilton, J. W. 1982. Choice of selection criteria in breeding for defined objective. Proc. 2nd World Cong. Genet. Appl. Livest. Prod., Madrid, Spain. I:60–69.

Wood, B. J., J. A. Archer, and J. H. J. van der Werf. 2004. Response to selection in beef cattle using IGF-1 as a selection criterion for residual feed intake under different Australian breeding objectives. Livest. Prod. Sci. 91:69–81.