Economic values for production and reproduction traits of Japanese Black (Wagyu) cattle from a bio-economic model

H. Hirooka[1] & K. Oishi[1]

[1] Kyoto University, Sakyoku, Kyoto 606-8502, Japan
hirooka@kais.kyoto-u.ac.jp

Summary

Economic values were derived for the Japanese Black (Wagyu) breed using a bio-economic model that simulates commercial integrated cow-calf-fattening systems in Japan. The breeding objective was profit maximization of life-cycle production of a cow and the investigated traits were carcass weight (CWT), beef marbling score (BMS), birth weight (BWT), 9-month weight (WT9), cow mature weight (MWT) and calving interval (CI; interval between first and second calving). The relative economic values (relative emphasis; %) for BMS, CWT, BWT, MWT, WT9 and CI were 257729 (24.4), 65783 (6.0), -1828 (0.2), -51464 (4.7), 46806 (4.3) and -676400 (61.5), respectively. CI was thus found to be the most important trait economically, even though this trait has low heritablity. Among production traits, BMS was still the most important in Japan. The extremely high economic values of CI in the present study relative to the previous studies may be reflected by the effect that extra days in CI implicitly lead to a reduction in reproductive performance (conception rate) and thereby in the number of calves born. It was therefore suggested that CI should be included in the breeding objectives of future Wagyu breeding schemes because of its high economic importance.

Keywords: beef cattle, bio-economic model, breeding objective, economic values, Wagyu

Introduction

The general breeding objective in beef cattle is to obtain successive generation of animals that will produce better products more efficiently in future production circumstances than in the present. Therefore, effective genetic improvement schemes require prior knowledge of importance of genetic changes in traits relating to breeding objectives (Hirooka *et al.,* 1998). Performance and progeny testing schemes for Japanese Black (Wagyu) cattle have been in operation for over 30 years in Japan, and remarkable genetic improvement in carcass traits (especially marbling) has been realized (Sasaki, 2001; Hirooka, 2014). Nevertheless, formal definition of breeding objective and an economic selection index based on aggregate genotype are still lacking for the breed, even though Hirooka *et al.* (1998) proposed breeding objectives for Japanese beef cattle production twenty years ago.

Reproductive performance is receiving increased attention in Wagyu breeding because genetic improvement of reproductive traits can lead to more profit for beef producers. The aim of this study was to derive economic values for several production and reproduction traits for Wagyu cattle under typical Japanese production circumstances using a bio-economic model that can describe the complex nature of beef production systems, taking into account genetic, nutritional, management and economic factors.

Materials and methods

Overview of the model

The model used in this study was based on the bio-economic deterministic model for Wagyu cow-calf production systems described by Oishi *et al.* (2013), adding the module of fattening processes. The herd composition dynamics of the model included three animal categories: steers (including growing and fattening stages), feedlot heifers (including growing and fattening stages), and replacement heifers and cows. The birth weight and the weight at the start of fattening of steers (ordinarily 9 month) were expressed as 1.2 times those of heifers, whereas the carcass weight, mature weight and average daily gain of heifers were 0.88 times those of steers. Body weight changes in each sex were estimated from the growth curves, which were represented by straight lines from birth to weaning, using Brody's curve from weaning to the start of fattening and the Gompertz curve in the fattening stage. The daily amounts and costs of feeds fed to animals that could satisfy animal's nutrient requirements were calculated by a least-cost feed formulation using linear programming. The carcass unit prices of fattening steers and heifers were calculated from a logistic function of the beef marbling score (BMS; 1 lowest to 12 highest), and that of culled cows was calculated by a quadratic function of BMS and culling parity. Such individual biological and economic outputs were multiplied by the animal numbers of the herd components. In the present study, self-replacement production was assumed; therefore, it was necessary to control the replacement rate of cows to maintain the herd size of breeding cows with changes in the conception rate and the planned culling parity of cows. The control of the replacement rate resulted in changes in the number of calves for fattening, which finally influenced the output of carcass sales. All simulations were conducted based on a one-day time step.

Calculation of calving interval and

In this model, the calving interval of a cow in each parity was estimated based on a single AI service conception rate per estrus cycle (product of estrus detection and AI conception probability). Single AI service conception rate of cows ($Cr(p)$) in parity *p* was calculated using the quadratic function that had a peak at the 3rd parity (Oishi *et al.* 2011) as

$$Cr(p) = Cr(1)/0.85718 \times (-0.7051p^2 + 6.2641p + 80.159)/100 \quad (1)$$

where *Cr(1)* is the single AI conception rate at the first parity (0.50 in the base situation). In the present study, the average days open (the average period from calving to the next conception) for all females at parity *p* (*DO(p)*, days) was expressed as the sum of the anoestrus postpartum interval and the average of mating trial period according to Bailie (1982) as follows:

$$DO(p) = (t_{pp} - t_{op}) + t_{op} \times Cr(p) + 2 \times t_{op} \times Cr(p)(1 - Cr(p)) + 3 \times t_{op} \times Cr(p)(1 - Cr(p))^2 + \cdots$$
$$= (t_{pp} - t_{op}) + t_{op} \times \sum_{i=1}^{mt} i(1 - Cr(p))^{i-1} \quad (2)$$

where mt is the number of AI services, t_{op} (days) is the mean length of the estrus cycle and for first mating, t_{pp} is equal to the sum of the weaning and post-weaning periods. The calving interval at parity p was calculated as the sum of days open and gestation length.

The total conception rate at the end of the maximum number of estrus cycles at parity p (*TCr(p)*) was calculated as

$$TCr(p) = Cr(p) + Cr(p)(1 - Cr(p)) + Cr(p)(1 - Cr(p))^2 + \cdots Cr(p)(1 - Cr(p))^{(mt-1)}$$

$$= Cr(p) \times \sum_{t=1}^{m} (1 - Cr(p))^{t-1} \quad (3)$$

Finally, calving rate determined as 0.98*TCr(p)* considering calf loss by the effects of abortions and of fetal and perinatal death. The constants t_{pp}, t_{op} and t_{preg} were set at 51, 21 and 285 days, respectively.

Estimation of economic values of traits

Economic values are derived by estimating the change of each objective trait (g_i) in profit resulting from a small change (Δg_i) in a given trait while holding all other traits and variables constant. As bio-economic models can be represented as a function of genetic (G), nutritional (N), management (M) and economic (E) variables, the economic value of trait *i* (EV_i) is calculated as

$$EV_i = \frac{f(g_i + \Delta g_i, M, N, E) - f(g_i, N, M, E)}{\Delta g_i} \quad (4)$$

where g_i is the mean of the breeding objective trait *i* and Δg_i is a small value by which the mean is genetically changed. The traits considered in the present study were beef marbling score (BMS), carcass weight (CWT), birth weight (BWT), mature weight (MWT), 9-month weight (WT9), and calving interval (CI; interval of first to second calving). The economic value of CI was estimated from the simulated profit based on change in single AI service conception rate in the first parity (*Cr(1)*) and change of simulated CI instead of *Cr(1)* used as Δg_i in Eq(4). Relative economic values (REV) were calculated as EV times the genetic standard deviation and the relative emphasis (%) for each trait was calculates by dividing the absolute value of relative economic value of each trait by the sum of the absolute values of the relative economic values of all traits.

Results and Discussion

Economic values, relative economic values and the degree of emphasis placed on each objective trait are presented in Table 1.

Table 1. Economic values (EV), relative economic values (REV) and relative emphasis placed on individual objective traits for Japanese Black (Wagyu) cattle.

Trait[1]	Base value	Genetic SD (σ_g)	Economic value (yen/trait unit)	REV (EV x σ_g)	Relative emphasis (%)
BMS, unit[2]	6	1.27	202,491	257,729	24.4
CWT,kg	480	35.3	1,863	65,783	6.0
BWT,kg	30	2.5	-726	-1,828	0.2
MWT,kg	480	66.4	-775	-51,464	4.7
WT9	290	17.7	2,640	46,806	4.3
CI,day	372	14.0	-48,192	-676,400	61.5

[1]BMS , beef marbling score; CWT, carcass weight; BWT, birth weight; MWT, mature weight; WT9, 9 month weight; CI, interval between first and second calving

[2]Mabling score units represented by a range of 1 to 12, with 12 being the highest

Surprisingly, the largest relative economic value was obtained for CI. CI was adopted as a reproductive trait in the present study, because a single AI service conception rate is difficult to record in commercial production situations in Japan. In addition, it was noted that non-seasonal year-around (continuous) mating by AI is conducted for beef cattle in Japan. Economic values of CI have been derived for the Piemontese breed in Italy (Albera *et al.*, 2004), and British and Continental breeds in Norway (Aby *et al.*, 2012) using bio-economic models. The economic values derived per cow per year basis were -2.60 EURO in Albera *et al.* (2004), and -1.47 EURO for British breeds and -0.97 EURO for Continental breeds in Aby *et al.* (2012). When expressed in Euro per cow per year, the economic value of CI in the present study was -51.5 EURO. The extremely large economic value may have resulted from the effect that a decreased day in interval exerts on the reproductive efficiency in the model; improved CI could lead to an enhanced conception rate and thereby increases in the number of calves and available fattening animals in the present study, while such effects were not considered and assumed to be unchanged in the previous studies. Again, in this study, days open (and thereby CI) assumed to be affected by conception rate (Bailie, 1982; Pecsok *et al.,* 1994).

Among production traits, BMS was estimated as having the largest positive economic value, indicating that marbling is still an economically important trait in Japanese markets. In the past, Hirooka *et al.* (1998) also reported marbling score as the most important trait for improving the economic breeding objective in Japan. Barwick and Henzell (1999) showed that the relative economic value for marbling score increased with the mean score for Australian beef production systems aimed at the high-quality Japanese beef market. Conversely, in a recent paper, Ochsner *et al.* (2017) reported that the relative emphasis on marbling score for Beefmaster cattle in a terminal U.S production system was low.

In conclusion, the results of the present analysis indicate that reproductive traits such as CI should be included in breeding objectives in future multiple-trait breeding schemes for Wagyu cattle in Japan.

List of References

Aby, B. A., L. Aass, E. Sehested & O. Vangen, 2012. A bio-economic model for calculating economic values of traits for intensive and extensive beef breeds. Livest. Sci. 143:259-269.

Albera, A., P. Carnier & A.F. Groen. 2004. Definition of a breeding goal for the Piemontese breed: economic and biological values and their sensitivity to production circumstances. Livest. Prod. Sci. 89:67-78.

Bailie, J.H. 1982. The influence of breeding management efficiency on dairy herd performance. Anim. Prod. 34:315-323.

Barwick, S. A. & A. L. Henzell. 1999. Assessing the value of improved marbling in beef breeding objectives and selection. Aust. J. Agric. Res. 50:503-512.

Hirooka, H. 2014. Marbled Japanese Black cattle. J. Anim. Breed. Genet. 131:1-2.

Hirooka, H., A. F. Groen & J. Hillers. 1998. Developing breeding objectives for beef cattle production. 2. Biological and economic values of growth and carcass traits in Japan. Anim. Sci. 66:623-633.

Ochsner, K. P., M. D. MacNeil, R. M. Lewis & M. L.Spangler. 2017. Economic selection index development for Beefmaster cattle I: Terminal breeding objective. J. Anim. Sci. 95:1063-1070.

Oishi, K., T. Ibi, A. K. Kahi & H. Hirooka. 2011. Optimal culling strategy in relation to

biological and economic efficiency and annualized net revenue in the Japanese Black cow-calf production system. J. Agric. Sci. 149: 783-799.
Oishi, K., Y. Kato, A. Ogino & H. Hirooka. 2013. Economic and environmental impacts of changes in culling parity of cows and diet composition in Japanese beef cow-calf production systems. Agric. Syst. 115: 95-103.
Pecsok, S. R., M. L. McGilliard & R. L. Nebel. 1994. Conception rates. 1. Derivation and estimates for effects of estrus detection on cow profitability. J. Dairy Sci. 77:3008-3015.
Sasaki, Y. 2001. Beef cattle breeding and its trend in Japan. Asian-Aust. J. Anim. Sci. 14, Special Issue:111-122.