Effects of Genetic and Environmental Factors on Ultrasonic Estimates of Carcass Traits of Japanese Brown Cows

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ABSTRACT : A study was made of the effects of genetic and environmental factors on ultrasonic estimates of carcass traits of Japanese Brown cows. The M. *longissimus thoracis* area (MLTA), Subcutaneous (SFT) and Inter Muscular (IMFT) Fat Thickness, Rib Thickness (RT) and Beef Marbling Score (BMS) were scanned at the 7th rib by ultrasound. Significant differences between sires, raising place, birth year and season were found for all traits. The heritabilities estimates for sire or Maternal Grand Sire (MGS) on ultrasonic estimates of carcass traits ranged from 0.05～0.14. Genetic and phenotypic correlations among the ultrasonic estimates were positive (0.13～0.88 and 0.24～0.75). Raising place effects were significant for all traits and the differences were between 30.8～33.5 cm^2 for MLTA and 0.46～0.67 for BMS. Cows born in 1988 tended to have high MLTA, SFT, IMFT and RT but low BMS. Cows born in spring tended to have high MLTA. Cows born in winter or autumn tended to have high BMS. The interaction effects of birth year with birth season were significant for both MLTA and BMS. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 4 : 506-510)*

Key Words : Japanese Brown Cow, Ultrasonic Estimates, Carcass Traits, Genetic Parameters

INTRODUCTION

Since Japan started beef trade liberalization on the 1st of April 1991 more efficient breeding strategies have been required for improve the domestic beef to compete with foreign beef in high quality beef production. The targets to improve Wagyu production are meat quality and meat quantity. Great attention has also been paid to select the breeding cow in the herd.

Japanese Brown cattle, especially Kumamoto strain, have larger mature size and growth rate than other domestic breeds but meat quality is lower relative to Japanese Black cattle (Namikawa, 1992). Therefore, the potential for improving the quality of carcass traits of Japanese Brown cow needs to be evaluated. For conduct of a successful breeding and selection program of Japanese Brown cows, an understanding of the degree of genetic, phenotypic and environmental influences affecting cow carcass traits, and associations among carcass traits are essential. There were no reports on genetic parameters of carcass traits of Japanese Brown cows. The use of ultrasound to estimate carcass traits precisely and accurately should benefit a genetic improvement program for Japanese Brown cows. Development of portable technology for ultrasound imaging of live animal offers a low-cost alternative to avoid the high cost of obtaining carcass records and from requiring progeny test which are very costly in terms of time and money (Leaflet, 1993; Wilson, 1992). Ultrasound also could be used for direct selection for carcass traits (Herring et al., 1994). In previous papers (Harada and Kumazaki, 1979, 1980; Harada et al., 1985, 1989; Harada, 1996; Perkins et al., 1992; Robinson et al., 1992) the accuracy and precision of using ultrasonic techniques for estimating carcass traits have been assessed. The purpose of this study was to estimate the genetic parameters from ultrasonic estimates of carcass traits of Japanese Brown cow and to clarify the effect of some factors such as sire, MGS within sire, raising place, birth year and birth season on the ultrasonic estimates.

MATERIALS AND METHODS

Experimental animals

Ultrasonic estimates of carcass traits were obtained from 9,468 cows (represented by 98 sires) born from January, 1988 to December, 1993 at Kumamoto prefecture. Every cow were ultrasonically scanned at first registration examination at 16.0～36.9 months of age.

Scanning procedures and traits

Ultrasonic scanning was done at the 7th rib on the left side of each animal to obtain carcass traits estimates of MLTA, SFT, IMFT, RT and BMS. Scanning equipment was Super-Eye MEAT (FHK Co. Ltd., Japan) with the electric liner probe (2 Mhz frequency, 27 mm × 147 mm). Each scanogram was interpreted by use of a digitizer for estimating all carcass traits.

Statistical methods

The data obtained were statistically analyzed to clarify the effects of sire, MGS within sire, birth year, birth season, raising place and the interactions of birth year with birth season. The linear and quadratic regressions of age at ultrasonic scanning for ultrasonic estimates of carcass traits were included in the model. Data were analyzed using Mixed Model Least-Squares and Maximum Likelihood Computer Programs of Harvey (1990) with the model as follows :

$$\hat{Y}_{ijklmn} = \mu + m_i + g_{ij} + Y_k + S_l + P_m + (YS)_{kl} + a_1(U_{ijklm} \bar{U}) + a_2\,(U_{ijklm} - \bar{U})^2 + e_{ijklmn}$$

where,

$\hat{Y}_{ijklmn}$ = the ultrasonic estimates of carcass traits

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μ = overall mean
m_i = random effect of the i^{th} Sire (i = 1, ⋯98)
g_{ij} = random nested effect of j^{th} MGS within i^{th} sire (j = 1, ⋯, 235)
Y_k = effect of the k^{th} birth year (k = 1988, ⋯, 1993)
S_l = effect of the l^{th} birth season (l = Winter, Spring, Summer and Autumn); Winter = Dec~Feb, Spring = March~May, Summer = June~Aug and Autumn = Sep~Nov)
P_m = effect of the m^{th} raising place (m=1, ⋯, 11)
$(YS)_{kl}$ = interaction effect of the k^{th} birth year with the l^{th} birth season
a_1, a_2 = coefficients of linear and quadratic regression of cow's age
$\bar{U}$ = mean of cow's age
e_{ijklmn} = residual error of the dependent variable

In the main mathematical model, both sire and MGS within sire effect were treated as random effects and the other sources of variance were considered as fixed effects. Another model, without the nested effects in the main model, ws used to estimate heritabilities, and genetic and phenotypic correlations. Duncan's test was used to test the differences within least squares means of carcass traits estimates.

RESULTS AND DISCUSSION

Ultrasonic estimates of carcass traits

Ultrasonic estimates of carcass traits of Japanese Brown cows showed variation among sires, raising place, birth year and birth season. The results of least squares analysis of variance for ultrasonic estimates of carcass traits are presented in table 1.

Genetic effects

Sire effects were significant ($p<0.01$) for all ultrasonic estimates of carcass traits. MGS within sire effects were significant for MLTA ($p<0.05$) and IMFT ($p<0.01$). However, the mean squares for sire effects were higher than that for MGS effects for all carcass traits. Several sires had high BMS and big MLTA size, and other sires had high BMS but small MLTA. Some sires had big MLTA but low BMS, or small MLTA and low BMS. Sires which have big MLTA and high BMS should be used as superior breeding sires to improve Wagyu meat production performance.

The heritability, genetic and phenotypic correlations from ultrasonic estimates of carcass traits of Japanese Brown cows are shown in table 2. The heritability estimates for both sire and MGS models were similar (0.06 for MLTA, 0.14 for SFT, 0.07 for IMFT, 0.05 for

Table 1. Analysis of variance for ultrasonic estimates of carcass traits of Japanese Brown cows (based on sire effect)

Source of variation	df	Mean squares[a]				
		MLTA (cm^2)	SFT (mm)	IMFT (mm)	RT (mm)	BMS
Sire	97	54.8**	72.7**	99.9**	182.8**	0.34**
MGS : Sire	2876	22.6*	16.3	38.2**	80.7	0.10
Place	10	323.8**	263.2**	401.8**	937.7**	1.06**
Birth year (Y)	5	546.9**	899.0**	4655.9**	4366.3**	2.25**
Birth season (S)	3	146.5**	127.2**	778.4**	226.7*	0.61*
(Y)×(S)	15	109.6**	63.8**	455.8**	347.3**	0.35**
Regression						
Age (Linear)	1	651.0**	195.8**	3115.6**	3918.1**	0.96**
Age (Quadratic)	1	554.5**	583.9**	210.0*	1636.9**	2.00**
Residual	6469	21.1	16.6	35.0	80.6	0.10

[a] MLTA : M. *Longisimus Thoracis* Area; SFT : Subcutaneous Fat Thickness; IMFT : Inter Muscular Fat Thickness; RT : Rib Thickness; BMS : Beef Marbling Score.

** $p<0.01$; * $p<0.05$.

Table 2. Genetic parameters for ultrasonic estimates of carcass traits of Japanese Brown cows (n = 9468)

Traits[a]	Heritability (h^2)		Correlation									
			MLTA		SFT		IMFT		RT		BMS	
	A	B	A	B	A	B	A	B	A	B	A	B
MLTA (cm^2)	0.06	0.06			0.52	0.54	0.67	0.70	0.72	0.76	0.71	0.72
SFT (mm)	0.14	0.14	0.46	0.45			0.65	0.66	0.66	0.68	0.13	0.15
IMFT (mm)	0.07	0.07	0.44	0.44	0.47	0.47			0.86	0.88	0.19	0.23
RT (mm)	0.05	0.05	0.56	0.56	0.57	0.57	0.75	0.75			0.34	0.40
BMS	0.10	0.10	0.36	0.36	0.35	0.35	0.24	0.25	0.32	0.32		

[a] Abbreviation of carcass traits are same as table 1.

A : based on sire model; B : based on maternal grand sire model.

Genetic and phenotypic correlation are above and below diagonal, respectively.

RT and 0.10 for BMS, respectively). Heritability estimates of MLTA in this study were lower than previous reports for Japanese Brown cows (Harada, 1996; Hirooka et al., 1996), Japanese Black females (Oyama et al., 1996) and Herefords (Arnold et al., 1991, Benyshek, 1981; Lamb et al., 1990; Turner et al., 1990). Heritability estimates of BMS were also lower than for Japanese Brown cows (Hirooka et al., 1996) and Herefords (Lamb et al., 1990). Those heritabilities may vary with method of analysis, differences in breed, in management system and feed quality, or the size of herds used to obtain data.

Genetic correlations among ultrasonic estimates of carcass traits were positive and ranged from 0.13~0.86 for the sire model and 0.15~0.88 for the MGS model. The correlations from the sire model were lower than those from the MGS model but the differences were small. The similarity in phenotypic correlations between sire and the MGS models indicate that genetic ability from sire were nearly same with from MGS and with assumption that environment or management system in both of herd were similar.

Genetic correlations between MLTA and SFT were 0.52 (based on sire model) and 0.54 (based on MGS model); MLTA and IMFT (0.67, 0.70), MLTA and RT (0.72, 0.76), MLTA and BMS (0.71, 0.72) were highly correlated. SFT were highly correlated with IMFT (0.65, 0.66) and RT (0.66, 0.68) but poorly with BMS (0.13, 0.15), IMFT were highly correlated with RT (0.86, 0.88) but poorly with BMS (0.19, 0.23). Moderate correlations were found between RT and BMS (0.34, 0.40). Nevertheless, almost all genetic correlations among carcass traits were high. This indicated that selection to increase size of MLTA would increase BMS and other fat thicknesses. These relationships were informative because they could be used as basic information in the selection of Japanese Brown cows based on their MLTA and BMS.

Phenotypic correlations among ultrasonic estimates of carcass traits were positive and ranged from 0.24~0.75 by sire model and 0.32~0.75 by MGS model. However, differences between those models were small. Phenotypic correlations from the sire model were similar to those from the MGS model, except between MLTA and SFT (0.46, 0.45) and between IMFT and BMS (0.24, 0.25). With both models, phenotypic correlations were similar and moderately correlated between MLTA and IMFT (0.44), between MLTA and BMS (0.36), between SFT and IMFT (0.47), between SFT and BMS (0.35) and between RT and BMS (0.32). High correlations were found between MLTA and RT (0.56) and between IMFT and RT (0.75). The high genetic correlations, especially between MLTA and BMS (0.71, 0.72), encourages Japanese Brown cattle farmers and breeders who aim to produce high quality and quantity of beef. Establishment of management and recording systems and also accurate genetic parameters will be valuable in efficient breeding program.

Environmental Effects : Raising place and birth year effects were significant (p<0.01) for all ultrasonic estimates of carcass traits. Birth season effects were significant for MLTA, SFT, IMFT (p<0.01) and RT and BMS (p<0.05).

Least squares means for ultrasonic estimates of carcass traits by raising place are shown in figures 1 and 2.

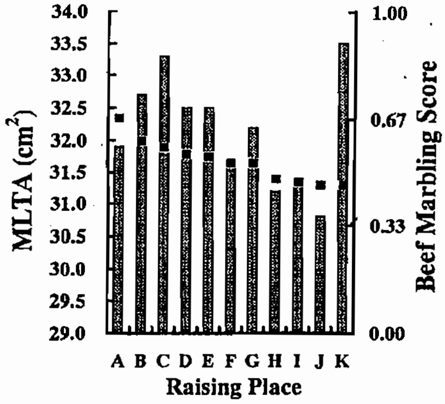

Figure 1. Ultrasonic estimates of MLTA and BMS of Japanese Brown Cow, by raising place

▨ MLTA ■ BMS

A: Kamimashiki; B: Kuma; C: Minami Aso; D: Tamana; E: Touhi; F: Kamoto; G: Yabe; H:Oguni; I: Aso; J: Kikuchi; K: Shimomashiki

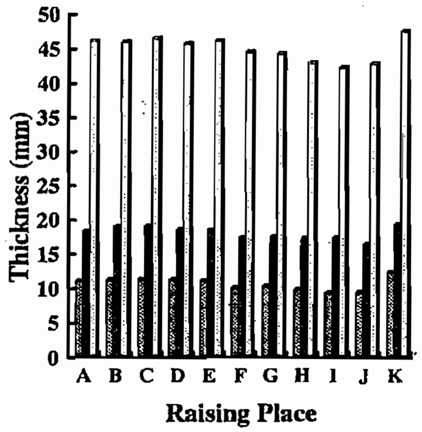

Figure 2. Ultrasonic estimates of SFT, IMFT and RT of Japanese Brown Cow, by raising place

▨ SFT ▩ IMFT ☐ RT

Abbreviations of raising place are same as figure 1.

There were differences in ultrasonic estimates of carcass traits between raising places because of the differences in management systems, quality and quantity of feed stuff, environment, and lines of sire. The cows raised at Shimomashiki had better meat quantity which had the highest mean MLTA (33.5±0.3 cm^2), SFT (12.0 ±0.4 mm), IMFT (19.0±0.4 mm) and RT (47.2±0.6 mm). Cows raised at Kamimashiki had better meat quality which had the highest mean BMS (0.67±0.03).

Cows raised at Kuma, Minami Aso and Tamana had equally high BMS and large MLTA. These indicate that raising place is also an important factor in achieving the genetic improvement goal.

Least squares means for ultrasonic estimates of carcass traits by birth year are shown in figures 3 and 4.

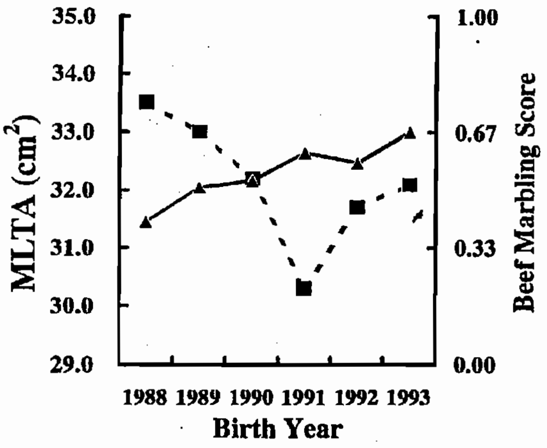

Figure 3. Pattern of ultrasonic estimates of MLTA and BMS of Japanese Brown Cows, by birth year

—■— MLTA —▲— BMS

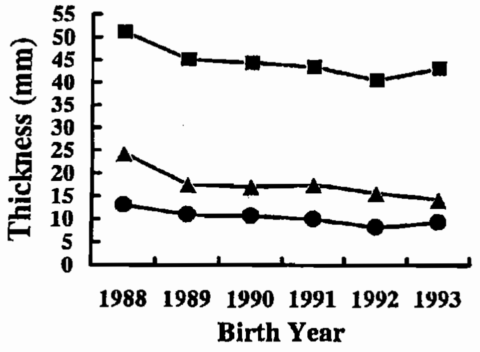

Figure 4. Pattern of ultrasonic estimates of SFT, IMFT and RT of Japanese Brown Cows, by birth year

—●— SFT —▲— IMFT —■— RT

The cows born in 1988 tended to have higher MLTA (33.5±0.4 cm^2), SFT (13.0±0.4 mm), IMFT (24.3±0.5 mm) and RT (51.2±0.7 mm) than those born in other years, but their BMS showed the lowest mean (0.41±0.02). Cows born in 1993 had the best BMS (0.67±0.02). MLTA slightly decreased from 1988 (by about 3.2 cm^2) to 1991 (30.3±0.3 cm^2) and then increased (by about 1.8 cm^2) to 1993 (32.1±0.3 cm^2). BMS also showed an increasing pattern from 1988 (0.41 ±0.02) to 1993 (0.67±0.02) except for a slight decrease (about 0.03) between 1991 and 1992. SFT and IMFT were decreasing from 1988 to 1993 (by about 3.7 mm and 10.0 mm, respectively) while their RT decreased (by about 10.7 mm) from 1988 to 1992 and then increased again (by about 2.7 mm) to 1993. The increase and decrease patterns of ultrasonic estimates of carcass traits show variability by birth year. Those were probably attributable to phenotypic effects and the influence of nutrition and environment. Therefore, the improvements of MLTA and BMS and reduction of fat thickness were due to the attention given to these traits by breeders in their selection program.

Least squares means of ultrasonic estimates of carcass traits by birth season are shown in figures 5 and 6.

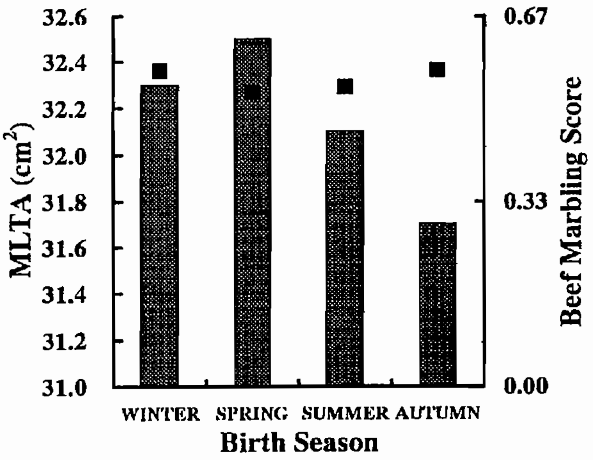

Figure 5. Ultrasonic estimates of MLTA and BMS of Japanese Brown Cows, by raising place

▨ MLTA ■ BMS

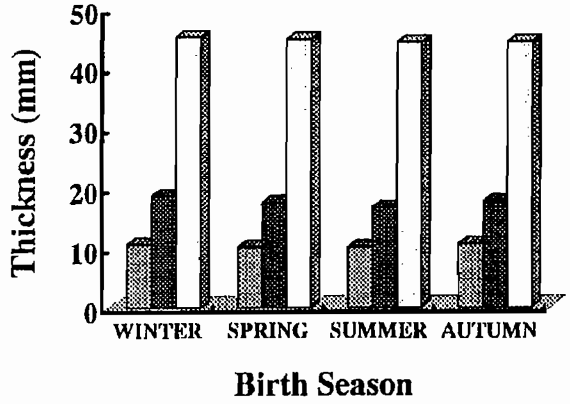

Figure 6. Ultrasonic estimates of SFT, IMFT and RT of Japanese Brown Cows, by raising place

▨ SFT ▨ IMFT ☐ RT

The cows born in spring had the biggest MLTA (32.5±0.2 cm^2). Cows born in winter or autumn had the thickest SFT (10.6±0.3 mm) and the highest BMS (0.57±0.02). IMFT (18.7±0.3 mm) and RT (45.2±0.4 mm) of cows born in winter were thicker than those in other seasons. The average MLTA of cows born in spring were bigger than those in winter (0.2 cm^2), summer (0.4 cm^2) or autumn (0.8 cm^2). The average BMS of cows born in winter and autumn were higher than those in spring (0.04) and summer (0.03). SFT average of cows born in winter and autumn were similar (0.5 mm) and were thicker than those in other seasons. The average IMFT of cows born in winter were thicker than those in spring (1.1 mm), summer (1.9 mm) or autumn (1.0 mm). In terms of RT average, cows born in winter were thicker than those in spring (0.4 mm), summer (0.9 mm) or autumn (0.8 mm), respectively.

The interaction effects of birth year with birth season were significant ($p<0.01$) for all ultrasonic estimates of carcass traits. The highest means were in spring 1988 for MLTA (34.5 ± 0.4 cm^2), and in winter 1993 for BMS (0.72 ± 0.03). However, the highest means interactions were in summer 1993 for both MLTA (33.2 ± 0.6 cm^2) and BMS (0.64 ± 0.04).

Quadratic regressions of MLTA, SFT and RT ($p<0.01$) and IMFT ($p<0.05$) were negative and significant affected by age. BMS was positive and significant ($p<0.01$) for linear regression while negative and significant ($p<0.01$) for quadratic regression. Those results indicated that increasing in age of Japanese Brown cows when ultrasonic scanned (within 16.0~36.9 months of age) tended to decrease all ultrasonic carcass trait estimates.

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