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Original Article (Full Paper)

Feasibility of using the ultrasound technique in the genetic improvement of young Japanese Black bulls

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ABSTRACT The objective of this study was to evaluate the feasibility of using the ultrasound technique in the genetic improvement of young Japanese Black bulls. Ultrasonic scanning was undertaken at approximately 11 months of age, between the 6th -7th and 12th-13th rib cross section on the left side in performance test stock to obtain ultrasonic carcass traits of rib eye area (REA7/13), trapezius muscle thickness (TMT), latissimus muscle thickness (LMT), rib thickness (RT), subcutaneous fat thickness (SFT), intermuscular fat thickness (IMFT) and beef marbling score (BMS). Data were collected from 525 young Japanese Black bulls at the Livestock Improvement Association of Miyazaki. Single trait analysis was conducted by applying a mixed model that included a random effect for sire and fixed effects for testing year and season. Age at the start of the performance test was included as a covariate. The variance components were estimated by the residual maximum likelihood procedure and heritability was computed. Except BMS all ultrasonic carcass traits had moderate heritabilities, ranging from 0.15 to 0.40. Selection based on the phenotypic values of these ultrasonic traits should be effective for the genetic improvement of young Japanese Black bulls.

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Keywords：Heritability, performance test stock, selection

Introduction

Since the formation of breeding stock unions in 1962 and the registration of animals based on their pedigree, body condition score and body measurements, significant progress has been made in Japanese Black cattle breeding to date. During the 1950s the concept of progeny testing arose and subsequent standardised procedures were formulated in 1962. In the year 1968, official performance and progeny testing programs were initiated in various prefectures. The best linear unbiased prediction (BLUP) animal model was later introduced to predict breeding values using field progeny testing records (Namikawa 1992). Considering this background the organised genetic improvement of the Japanese Black breed stretches back to about 50 years ago. Nevertheless, the program could be improved by reducing the generation intervals through early prediction of carcass traits, resulting in more gains per unit time and reduced costs. Currently, the information used to predict carcass merit is collected through structured carcass sire progeny tests. Carcass sire progeny tests are time consuming, expensive, and may be subject to more selection bias compared to evaluations based on live animal carcass traits (Sapp *et al*. 2002). Progeny testing, as the name implies, is a selection criterion based on the mean value of an individual's progeny. In practise, however, it suffers from serious drawback of much lengthened generation interval, because the selection of parents cannot be carried out until the offspring have been measured (Falconer 1981). Furthermore, progeny based selection methods may be biased because the parent being selected provides only half of the genes in the progeny, the other half may come from a superior or inferior mate giving an advantage or disadvantage to the parent in question (Falconer 1981). However, a number of ways have been innovated to assess live animal carcass traits, these include: ultrasound (US), mechanical and optical probes, electromagnetic scanning, electrical impedance, computer tomography and nuclear magnetic resonance (Wilson 1992). Computer tomography has been highlighted to be more accurate in

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predicting the body composition, however, US is much cheaper, quicker and easier to operate and has the tremendous advantage of mobility (Junkuszew and Ringdorfer 2005). The ultrasound technique has been demonstrated to be satisfactory in predicting rib eye area (REA), rib thickness (RT), subcutaneous fat thickness (SFT) and intermuscular fat thickness (IMFT) (Stouffer *et al.* 1961; Davis *et al.* 1966; Forrest *et al.* 1989). As alluded to previously, ultrasound facilitates the selection of individuals to be done in accordance with their own phenotypic values hence avoid the bias that may be attributed to using progeny phenotypic values.

Heritability informs the breeder how much confidence to place in the phenotypic performance of an animal when selecting parent stock. For highly heritable traits, where heritability exceeds 0.40, the animal's phenotype is a good indicator of genetic merit or breeding value. For lowly heritable traits, where heritability is below 0.15, an animal's performance is less useful in identifying the individuals with the best genes for the trait (Cassell 2009). Studies have shown that ultrasound measurements of fat thickness, REA and intramuscular fat percentage are moderate to high in heritability (Bertrand *et al.* 2001). Though ultrasonic measurements are currently collected in a number of prefectures in Japan; there is little information available in literature to assess the feasibility of genetic improvement of Japanese Black cattle based on these measurements. The objective of this study was to estimate heritabilities for ultrasonic measures of carcass traits in young Japanese Black cattle.

Materials and Methods

The data used in this study were collected from 525 young Japanese Black bulls at the Livestock Improvement Association of Miyazaki. The young bulls, performance tested from 1990 to 2012 were progeny of 67 sires and 334 dams. Each year, 20-30 bull calves were selected from designated farms within an age bracket of 6-7 months and a body weight range of 200-300 kg. All bulls were performance tested for 112 days at the station and housed in individual stalls with an adjacent paddock for voluntary exercise. After three weeks of being introduced to the feed, the animals were provided *ad libitum* access to roughage; however, feeding concentrate was restricted to twice a day. In addition to roughage and concentrate, water was supplied *ad libitum*. Sufficient feed was given to each animal based on prior consumption. Records of roughage and concentrate consumption were maintained on dry a matter basis.

Ultrasonic scanning was done at approximately 11 months of age on the left side in performance test stock. All traits except rib eye area (REA) were measured between the 6^{th} -7^{th} rib cross section only. REA was also measured between the 12^{th}-13^{th} rib cross section. Ultrasonic carcass traits of rib eye area (REA7/13), trapezius muscle thickness (TMT), latissimus muscle thickness (LMT), rib thickness (RT), subcutaneous fat thickness (SFT), intermuscular fat thickness (IMFT) and beef marbling score (BMS) were measured. The TMT was measured at the mid-point of the trapezius muscle while LMT was measured along the orthogonal line with skin surface, from the iliocostalis muscle. Both SFT and IMFT were measured along the same line with LMT. The RT was defined as the distance between the latissimus muscle and pleural membrane, measured 3.4 cm (laterally) from the edge of the iliocostalis muscle. Scanning equipment utilised in this study was SEM-500 (FHK Co. Ltd. Japan) and HS-2000 (FHK Co. Ltd. Japan) using a frequency of 2 MHz. All linear and areal measurements were conducted using image analysis software (ImageJ version 1.46r). BMS was assessed subjectively through visual appraisal on a scale ranging from 0.0 (lowest) to 3.0 with intervals of 0.33, and from 4.0 to 5.0 (highest) with an interval of 1.0 (Nishimura *et. al.* 1995). All ultrasound measurements were conducted by members of the Animal Breeding and Genetics Laboratory, University of Miyazaki.

Firstly, the data were subjected to least squares analysis of variance using JMP® 5.0.1 (SAS Institute Inc., Cary, NC, USA). Furthermore, variance components were estimated by the REML procedure using the same software. Single trait analysis was undertaken by applying a mixed model that included a random effect for sire and fixed effects for testing year and season. Age at the start of the performance test was included as a covariate. Heritability was computed using the sire components of variance and the pooled sire and error components of variance in the manner of half-sib families. Standard errors of estimates of heritability were calculated by formulas of Falconer (1981) as implemented by Carnier *et al.* (2000).

Results and Discussion

Means, standard deviations (SD), minimum and maximum values for each variable are presented in Table 1. The mean for REA at the 12th rib position in the current study was smaller than those reported by Reverter *et al.* (2000); the authors reported values of 72.0 cm^2 and 68.7 cm^2 in Australian Angus and Hereford yearling bulls respectively. A study involving multiple breeds by Perkings *et al.* (1992) showed mean values of 76.3 cm^2, 67.1 cm^2, and 64.0 cm^2 in Brown Swiss steers, Zebu-cross Mexican steers and Corriente Mexican steers respectively. The SFT reported in this study was similar to reports on most foreign breeds (De Rose *et al.* 1988; Lamb *et al.* 1990; Shepard *et al.* 1996).

The least squares means and standard errors of ultrasonic carcass traits are presented in Table 2. Starting season did not significantly affect REA, TMT, LMT, RT, and BMS; however, it significantly affected both SFT and IMFT. The cattle that

Table1 Data summary including description of ultrasonic traits, units of measurements, number of records, means, minimum and maximum values

Trait	Description	Units	Records	Mean ± SD†	Min†	Max†
REA7	rib eye area at the 6th-7th rib cross section	cm^2	525	31.9 ± 2.1	22.3	37.9
REA13	rib eye area at the 12th-13th rib cross section	cm^2	525	53.6 ± 4.3	37.7	73.0
TMT	trapezius muscle thickness	mm	525	12.9 ± 1.1	10.2	15.3
LMT	latissimus muscle thickness	mm	525	12.9 ± 1.2	10.1	19.3
RT	rib thickness	mm	525	40.2 ± 3.4	25.4	64.9
SFT	subcutaneous fat thickness	mm	525	6.1 ± 1.7	1.9	15.3
IMFT	intermuscular fat thickness	mm	525	14.4 ± 3.6	4.8	28.1
BMS	beef marbling score	-	525	0.74 ± 0.2	0.33	1.67

† SD = standard deviation, Min = minimum value, Max = maximum value.

Table2 Least squares means and associated standard errors for ultrasonic traits

	Effect						
	Year	Age	Season				
Trait†				Spring	Summer	Autumn	Winter
REA7 (cm^2)	**	ns	ns	31.62 ± 0.25	31.63 ± 0.21	32.17 ± 0.25	32.04 ± 0.19
REA13 (cm^2)	**	ns	ns	53.16 ± 0.52	53.27 ± 0.44	53.71 ± 0.53	53.25 ± 0.39
TMT (mm)	**	*	ns	12.70 ± 0.13	12.94 ± 0.11	12.92 ± 0.13	12.88 ± 0.09
LMT (mm)	**	*	ns	12.62 ± 0.14	12.91 ± 0.11	12.99 ± 0.14	12.85 ± 0.10
RT (mm)	**	ns	ns	39.09 ± 0.47	39.76 ± 0.39	39.60 ± 0.50	40.35 ± 0.32
SFT (mm)	**	*	*	5.30^a ± 0.21	6.03^b ± 0.18	6.21^b ± 0.21	6.05^b ± 0.16
IMFT (mm)	**	ns	*	13.60^a ± 0.43	14.88^b ± 0.35	14.11^b ± 0.41	14.82^b ± 0.31
BMS	**	*	ns	0.70 ± 0.30	0.75 ± 0.02	0.78 ± 0.03	0.73 ± 0.02

† REA7 = rib eye area at the 6th-7th rib cross section, REA13 = rib eye area at the 12th-13th rib cross section, TMT = trapezius muscle thickness, LMT = latissimus muscle thickness, RT = rib thickness, SFT = subcutaneous fat thickness, IMFT = intermuscular fat thickness, BMS = beef marbling score.

a, b Row means with different superscripts differ significantly at $P < 0.05$.

*: $P < 0.05$, **: $P < 0.001$, ns = not significant.

Table3 Estimates of variance components and heritability with standard errors for ultrasonic traits

Trait†	Parameter‡		
	Var(a)	Var(p)	h^2
REA7	1.833	4.745	0.39 ± 0.19
REA13	8.001	20.526	0.39 ± 0.19
TMT	0.211	1.345	0.16 ± 0.17
LMT	0.184	1.548	0.15 ± 0.17
RT	1.858	11.720	0.16 ± 0.17
SFT	1.277	3.219	0.40 ± 0.19
IMFT	3.259	13.812	0.24 ± 0.18
BMS	0.006	0.058	0.10 ± 0.16

† REA7 = rib eye area at the 6^{th}-7^{th} rib cross section, REA13 = rib eye area at the 12^{th}-13^{th} rib cross section, TMT = trapezius muscle thickness, LMT = latissimus muscle thickness, RT = rib thickness, SFT = subcutaneous fat thickness, IMFT = intermuscular fat thickness, BMS = beef marbling score.
‡ The term Var(a) is the additive genetic variance, Var(p) is the phenotypic variance, h^2 is the heritability for direct effects.

entered performance test in spring season exhibited significantly lower levels of subcutaneous and intermuscular fat thickness. These lower levels could be attributed to the hot season during which they were tested. In the performance test starting from spring, the cattle have to get through most of the hot summer season. These animals consequently have reduced feed intake and fat deposition. Except fat thickness, seasonal effects did not affect other traits; this is in agreement with reports by Chistison *et al.* (1990) and Bergen *et al.* (1997). The testing year had a highly significant effect on all ultrasonic carcass traits. Age of cattle at the start of the test did not significantly affect REA, RT and IMFT; however, it significantly affected TMT, LMT, SFT and BMS.

Variance components and heritability estimates for ultrasonic traits are presented in Table 3. Heritability for REA7 (0.39) was within the range of estimates by Fukuhara *et al.* (1989) in Japanese Black steers and Hirooka *et al.* (1996) in Japanese Brown steers. A comprehensive review by Oyama (2011) indicated a heritability range of 0.28-0.61 in Japanese Black cattle. The same study also reported a heritability range of 0.29-0.44 in Japanese Brown cattle. In a study by Kim *et al.* (2006) four different models were employed to estimate genetic parameters for carcass traits in Japanese Black cattle, the study reported estimates ranging from 0.19 to 0.31 for carcass REA. On the contrary, Kuchida *et al.* (1990), Arnold *et al.* (1991), Mukai *et al.* (1993) and Mukai (1994) obtained higher estimates of heritability than the present study: 0.65, 0.46, 0.54 and 0.45 in different breeds respectively. These differences could be attributed to variation in breed, age, management and gene frequencies in the populations reported on by these authors.

The heritability estimate of REA13 (0.39) obtained in this study was higher than some previous estimates. Turner *et al.* (1990) estimated the heritability value of REA13 to be 0.21 while Arnold *et al.* (1991) reported an estimate of 0.28. Robinson *et al.* (1993) and Shepard *et al.* (1996) estimated heritability of REA13 to be 0.24 and 0.11 in Angus cattle respectively. In yearling Brangus cattle, Moser *et al.* (1998) reported an estimate of 0.29. Estimates similar to this study were reported by Wilson *et al.* (1992) in Angus cattle (0.40). Furthermore, an estimate of 0.40 was reported by Johnson *et al.* (1993) in Brangus cattle.

Heritability estimates of TMT and LMT in this study were 0.16 and 0.15 respectively. To our knowledge they are no reports on the heritability of ultrasonic TMT and LMT. However, image analysis estimates of trapezius and latissimus muscle area had heritability values considerably higher than the current study. Osawa *et al.* (2004) found heritability values of 0.55 and 0.67 for trapezius and latissimus muscle area in Japanese Black cattle. In a similar study involving Japanese Black steers Osawa *et al.* (2007) reported a heritability of 0.47 for trapezius muscle area. There is need to research the phenotypic and genetic relationship between ultrasonic measures of TMT, LMT and the corresponding areal measurements in carcasses. The heritability estimate for RT (0.16) was slightly lower than most estimates in literature. Fukuhara *et al.* (1989) reported an estimate of 0.23 while Mukai *et al.* (1993) and Hirooka *et al.* (1996) had estimates of 0.29 and 0.26. The ultrasonic RT considered in this study is measured using a different position from that used in slaughter houses; this might therefore, lead to different estimates.

The estimated heritability for SFT (0.40) was in the same range as estimates by Koch *et al.* (1982). Their heritability estimate was from data pooled across 16 different sire breeds. DeRose *et al.* (1988) reported a heritability estimate of 0.49 in Angus cattle. On the contrary, lower estimates were reported by a number of authors. Lamb *et al.* (1990) reported an estimate of 0.24 while Arnold *et al.* (1991) reported a similar estimate of 0.26. Some estimates are higher than those presented in this study. Kuchida *et al.* (1990) and Shepard *et al.* (1996) reported estimates of 0.62 and 0.56 respectively. Intermuscular fat thickness (IMFT) heritability in the current study was estimated to be 0.24. Though few reports on the heritability of this trait are available in Japanese Black cattle because it is not included in the equation for calculating yield score in slaughter houses; yield score may be reduced if IMFT is deemed too thick.

In the current study a considerably low heritability (0.1) was obtained for BMS. The current estimate falls out of the range of values stated in a recent review by Oyama (2011). He indicated a range of 0.32-0.63 and unweighted and weighted heritability means of 0.49 and 0.61respectively in Japanese Black cattle. In the current study BMS exhibited very little genetic variation. It has been long thought that intramuscular fat or marbling is a late developing tissue. Marbling develops at a late stage because feed components fed to cattle are first consumed in bone growth, then muscle growth and finally fat development. The results of this study are in agreement with this theory considering the tender age (11 months) of cattle sampled in this study.

This study revealed that it is feasible to improve most ultrasonic carcass traits in young breeding cattle through selection. However, it is noteworthy that the final product of beef cattle is meat that they produce at slaughter. Hence, future studies need to verify the relationship between the ultrasonic carcass traits measured in young breeding stock and actual carcass traits of their progeny.

Conclusions

Heritability estimates for rib eye area, rib thickness, muscle and fat thickness ranged from 0.15-0.40. The moderate heritabilities of these traits signify that their phenotypic values are moderate indicators of genetic merit or breeding values. This implies that most ultrasonic traits in young Japanese Black bulls could be improved genetically through selection. However, the heritability for marbling score was low, implying that phenotypic measures of this trait are less useful in identifying the individuals with best genes for the traits. Taking ultrasonic measurements to determine marbling at an older age might result in higher heritability estimates to facilitate selection for this trait.

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要　約

超音波診断による黒毛和種種雄牛の選抜に関する研究

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種雄牛候補牛の選抜を行うための検定である産肉能力検定直接法 (直接検定) は，増体能力や飼料効率等に重きを置かれた選抜であるため，産肉形質に関する個体選抜としては必ずしも十分ではなく，産肉能力に優れた種雄牛を造成する上で，早期かつ正確に優良種雄牛を選抜する手法の確立が急務とされている．そこで本研究は，1990 ～ 2012 年までに宮崎県において直接検定を受検した 525 頭の種雄牛候補牛を供試牛として，検定牛の超音波診断により得られた個体自身の産肉形質測定値の分散成分および遺伝率を推定することを目的とした．超音波測定で得られた分析対象形質は，およそ 11 ヶ月齢の直接検定牛の生体左側第 6-7 および第 12-13 肋骨間横断面におけるロース芯面積 (REA7/13)，第 6-7 肋骨間横断面における皮下脂肪厚 (SFT)，筋間脂肪厚 (IMFT)，バラ厚 (RT)，脂肪交雑 (BMS)，僧帽筋厚 (TMT) および 広背筋厚 (LMT) である．分散成分および遺伝率を推定するために，JMP® 5.0.1 プログラムを用いて最小自乗分散分析および単形質解析 REML 法を行った．分析にあたり，要因効果として，種雄牛を変量効果，検定年度および検定開始季節を母数効果，開始時月齢を回帰に取り上げた．本研究で取り上げた産肉形質の中で REA7/13，SFT，IMFT，RT，TMT および LMT は，中程度の遺伝率が推定され，直接検定中の超音波測定によって得られる個体自身の産肉形質が遺伝的改良に利用できる可能性が示唆された．

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