Heritabilities and Genetic Correlation, and Sire and Environment Effects on Meat Production Potential of Hanwoo Cattle

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ABSTRACT : Genetic parameters of live weight at slaughter (LWT), quantity index (QIX), yield grade (YGD), quality grade (QGD), pH of meat, and boiled meat tenderness in terms of mastication (BMAS), shear force (BSFR) and penetration (BPEN) in Hanwoo steers were estimated. Effects of sire, location and their interaction on these traits were also evaluated. Sire effects were found to be significant on all the traits studied except for pH and BSFR. The LWT, QIX and QGD were also significantly affected both by location and by interaction effect between sire×location. The BSFR and BPEN were significantly ($p<0.01$) affected by location but not significantly by sire×location interaction. The boiled meat tenderness and pH were negatively correlated (r_g and r_p) with LWT, QIX and QGD. All the other traits were positively correlated with each other. Positive and high genetic correlation (+0.56) between LWT and QGD was obtained indicating that selection for LWT would improve QGD. The h^2 estimates were 0.43, 0.37, 0.37, 0.35 and 0.32 for QGD, LWT, pH, BSFR and BPEN, respectively. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 1 : 1-5)***

Key Words : Genetic Parameters, Quantity Index, Yield Grade, Quality Grade, Boiled Meat Tenderness

INTRODUCTION

Hanwoo, the main beef cattle breed in Korea historically known as a unique breed, have been bred to be a producer of high quality meat (Kim et al., 1998). Slaughter grade standards are based on factors which are related to quality grade and yield grade of beef carcass. In Korea, beef quality grades are determined especially by degree of marbling (intra-muscular fat). The tenderness of meat depends on several factors. Meat with high pH is more susceptible to bacterial spoilage and has reduced flavor. Nevertheless, this meat is associated with a higher rate of tenderization (Watanabe et al., 1996) or with better tenderness (Bouton et al., 1973).

In Hanwoo, individual bulls have genetic influences in the population because large numbers of progeny are produced by artificial insemination. In most situations, breeding beef bulls are evaluated based on their own yearling weight and growth rate. Estimation of genetic parameters in body weights of Hanwoo were made by some researchers (Shin and Park, 1990; Son et al., 1997). Growth rate and live weight are correlated with carcass traits but the correlation may not be strong enough to improve Hanwoo. Using the results of progeny test leads to improved reliability for individual evaluation of bulls. Despite the endeavor to improve Hanwoo, the information on the merit of carcass with the effects of genetic and environment is limited.

Meat traits of cattle have been studied considerably, and most of the traits have been found to be of high or moderate heritability (Robinson et al., 1990; Arnold et al., 1991; Gregory et al., 1994; Wheeler et al., 1996). However, the results cannot be easily generalized into the Hanwoo population, because most of the studies have involved European beef breeds that are only of marginal importance in Korea. The aim of this study was to investigate the sire, location and interaction between sire and location factors affecting meat characters in Hanwoo steers and to estimate heritability, genetic and phenotypic correlations between meat parameters.

MATERIALS AND METHODS

This experiment was undertaken at the laboratory of Animal Resources and Biotechnology, Chonbuk National University, Korea. A total of 161 progeny aged between 657-753 days (average 717 days) belonged to 23 sire groups were used in this study. The experimental animals were reared in two locations, Namwon and Taekwanryung branches of National Livestock Research Institute (NLRI). The meat samples were collected from 13th-14th ribs of the steers within 24 h of slaughter and evaluated by Fudo Rheo Meter and physical means. The traits studied were live weight at slaughter (LWT), carcass quantity index (QIX), carcass yield grade (YGD), carcass quality grade (QGD), pH of meat, boiled meat tenderness in terms of mastication (BMAS), shear force (BSFR) and penetration (BPEN). Carcass weights (CWT) were obtained by weighing the weight of slaughtered steers after the removal of the lungs,

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heart, liver, intestines and ancillary organs or mesenteries, bladder, reproductive organs and blood. The QIX of individual progeny were calculated using the following formula according to National Farmer's Cooperatives Federation (NFCF, 2000):

$$QIX=65.834-[0.393\times \text{back fat (mm)}]+[0.088\times \text{EMA (cm}^2)]-[0.008\times \text{CWT (kg)}]+2.01$$

The YGD were expressed as A, B or C based on the average QIX score such that A≥69 QIX, B 66-<69 QIX, and C<66 QIX score. The QGD were ranked on the scale of 4 to 1 (1+, 1, 2 and 3 grades) on the basis of marbling by visual assessment. The pH was measured directly in the raw muscle using pH meter. Meat tenderness was estimated using Fudo Rheo meter after boiling the samples at 65°C for 30 min.

Statistical analysis

(Co)variance components for LWT, QIX, QGD, pH, BMAS, BSFR and BPEN were analyzed by least squares techniques of the GLM procedures using SAS statistical package (SAS, 1991). In the model, all effects were considered as fixed effects except error effects. The statistical model used for the analysis of meat traits was as follows:

$$Y_{ijk}=\mu+S_i+L_j+(S\times L)_{ij}+e_{ijk}$$

Where, Y_{ijk}=individual record

μ=overall mean
S_i=effect of sire (i=1-23)
L_j=effect of location (j=1-2)
$(S\times L)_{ij}$=interaction effect between sire and location
e_{ijk}=residual error

Duncans Multiple Range Test (DMRT) was performed to separate means of significant difference. Values of h^2 and correlations (r_g and r_p) were estimated based on paternal half sib analysis method (Becker, 1985) involving 23 sire groups.

RESULTS AND DISCUSSION

Effects of sire

Effects of sire on LWT, QIX, YGD and QGD in Hanwoo steers are presented in Table 1. The LWT, QIX and QGD were significantly affected by individual sire. The highest LWT (590.5 kg), QIX (69.99) and QGD (3.25) were observed in the progeny derived from sire 528, sire 529, and sire 535, respectively. Sire effects on pH and boiled meat hardness are presented in Table 2. The pH and BSFR were not affected by sire but BMAS and BPEN were affected significantly ($p<0.05$) by individual sire. The highest BMAS (511.8 g/cm^2) and BPEN (8,922 g/cm^2) were observed in the progeny produced from sire 535 and sire 515, respectively. These genetic differences among sires could be utilized by selective breeding to produce beef cattle with greater genetic ability to meat quality and quantity.

Effects of location

Effects of location on meat quality and quantity in Hanwoo steers are presented in Table 3. Table 3 showed that the location had a significant effect on LWT ($p<0.05$), QIX ($p<0.05$), QGD ($p<0.01$), BSFR ($p<0.01$) and BPEN ($p<0.01$). The progeny reared in Namwon area, irrespective of sire, produced more LWT, QIX and QGD (554.2 kg, 69.65, and 2.36, respectively) than those in Taekwanryung area (539.5 kg, 69.19 and 1.94, respectively). Boiled meat

Table 1. Progeny performance (LWT, QIX, YGD and QGD) of different sires of Hanwoo cattle

Traits	Sire[1]											
	441 (4)	513 (10)	514 (7)	515 (3)	516 (6)	517 (6)	519 (7)	522 (9)	523 (4)	524 (6)	525 (9)	526 (9)
LWT (kg)	490.0^{c}	519.0^{bc}	565.7^{ab}	516.7^{bc}	573.3^{ab}	566.7^{ab}	524.3^{bc}	567.8^{ab}	550.0^{abc}	560.0^{ab}	536.7^{abc}	541.1^{abc}
QIX	69.64^{abc}	68.98^{abc}	69.35^{abc}	69.87^{ab}	69.49^{abc}	69.35^{abc}	68.78^{abc}	68.85^{abc}	69.49^{abc}	69.33^{abc}	69.42^{abc}	68.79^{abc}
YGD	A	B	A	A	A	A	B	B	A	A	A	B
QGD	2.25^{abcd}	2.30^{abcd}	2.14^{bcd}	2.00^{bcd}	1.67^{cd}	1.53^{d}	1.71^{cd}	1.56^{d}	3.00^{ab}	2.67^{abc}	2.33^{abcd}	2.00^{bcd}
Traits	Sire[1]											
	528 (4)	529 (11)	530 (8)	531 (9)	533 (3)	535 (4)	539 (9)	540 (8)	541 (13)	542 (6)	543 (6)	LS
LWT (kg)	590.5^{a}	529.1^{abc}	570.0^{ab}	535.6^{abc}	576.7^{ab}	577.5^{ab}	546.7^{abc}	573.8^{ab}	546.9^{abc}	516.7^{bc}	566.7^{ab}	*
QIX	67.98^{bc}	69.99^{a}	69.30^{abc}	69.64^{abc}	69.02^{abc}	67.83^{c}	69.75^{ab}	69.43^{abc}	69.13^{abc}	68.55^{abc}	69.10^{abc}	*
YGD	B	A	A	A	A	C	A	A	A	B	A	-
QGD	2.25^{abcd}	2.09^{bcd}	2.25^{abcd}	3.22^{a}	3.00^{ab}	3.25^{a}	2.44^{abcd}	2.13^{bcd}	1.85^{cd}	1.83^{cd}	2.33^{abcd}	**

[1] Figures in the parentheses indicate the number of progeny for each sire; LWT=Live weight; QIX=Quantity index; YGD=Yield grade; QGD=Quality grade.
[abcd] Means with different superscript(s) in the same row differ significantly; LS=Level of significance; * $p<0.05$; ** $p<0.01$.

Table 2. Progeny performance (pH and boiled meat hardness) of different sires of Hanwoo cattle

	Sire[1]											
Traits	441 (4)	513 (10)	514 (7)	515 (3)	516 (6)	517 (6)	519 (7)	522 (9)	523 (4)	524 (6)	525 (9)	526 (9)
pH	5.83	5.83	5.88	5.89	5.87	5.87	5.90	5.89	5.88	5.92	5.85	5.89
BMAS (g/cm^2)	228.1^{c}	315.5^{abc}	372.3^{abc}	240.2^{bc}	405.8^{abc}	348.4^{abc}	316.5^{abc}	419.3^{ab}	420.8^{ab}	387.5^{abc}	400.5^{ab}	316.1^{ab}
BSFR (g/cm^2)	6,241	5,919	6,155	5,549	7,040	6,740	6,311	6,462	6,346	5,573	6,276	6,137
BPEN (g/cm^2)	7,934^{ab}	6,842^{ab}	7,282^{ab}	8,922^{a}	6,147^{ab}	7,218^{ab}	5,813^{bc}	5,590^{bc}	5,562^{bc}	7,310^{ab}	5,863^{bc}	7,169^{ab}
	Sire[1]											
Traits	528 (4)	529 (11)	530 (8)	531 (9)	533 (3)	535 (4)	539 (9)	540 (8)	541 (13)	542 (6)	543 (6)	LS
PH	5.84	5.87	5.86	5.86	5.90	5.87	5.85	5.85	5.87	5.92	5.93	NS
BMAS (g/cm^2)	446.7^{ab}	340.4^{abc}	315.5^{abc}	362.0^{abc}	485.3^{ab}	511.8^{a}	325.3^{abc}	395.4^{abc}	279.3^{abc}	446.4^{abc}	284.1^{abc}	*
BSFR (g/cm^2)	5,328	6,068	5,834	5,544	6,576	5,569	6,257	6,074	5,745	5,827	6,531	NS
BPEN (g/cm^2)	5,898^{bc}	5,909^{bc}	7,824^{ab}	5,904^{bc}	7,802^{ab}	5,930^{bc}	6,581^{abc}	5,649^{bc}	5,613^{bc}	4,147^{bc}	5,370^{bc}	*

[1] Figures in the parentheses indicate the number of progeny for each sire : BMAS=boiled meat mastication; BSFR=boiled meat shear force; .BPEN=boiled meat penetration.

[abc] Means with different superscript(s) in the same row differ significantly; LS=Level of significance: * p<0.05: NS=Non-significant.

Table 3. Effects of location on meat characters in Hanwoo cattle

Location	Traits[1]							
	LWT (kg)	QIX	YGD	QGD	pH	BMAS (g/cm^2)	BSFR (g/cm^2)	BPEN (g/cm^2)
NWN (96)[2]	554.2^{a}	69.65^{a}	A	2.36^{a}	5.86	339.2	5,766^{b}	5,566^{b}
TKG (65)	539.5^{b}	69.19^{b}	A	1.94^{b}	5.89	388.7	6,450^{a}	6,840^{a}
MS	8,293.56	12.21	-	17.84	0.02	94,860	18,114,716	62,943,200
LS	*	*	-	**	NS	NS	**	**

[1] LWT=Live weight; QIX=Quantity index; YGD=Yield grade; QGD=Quality grade; BMAS=Boiled meat mastication; BSFR=Boiled meat shear force; PEN=Boiled meat penetration.

[2] Figures in the parentheses indicate the number of observations for each location.

LS=Level of significance * p<0.05; ** p<0.01; NS=Non-significant; MS=Mean square.

tenderness were found to be higher in Taekwanryung area (6.450 g/cm^2 and 6.840 g/cm^2 for BSFR and BPEN, respectively) than Namwon area (5.766 g/cm^2 and 5.566 g/cm^2 for BSFR and BPEN, respectively). Hence, management seems to play an important role in the production of animals of heavier live-weight as well as better meat quality and quantity. However, the YGD, pH and BMAS were not affected significantly by location in this population.

Interaction effects of sire x location

The interaction effects between sire and location on meat traits are presented in Table 4. The LWT, QIX and QGD were significantly ($p<0.05$) affected by the interaction effect, whereas the other traits were not affected by interaction between sire and location. These imply that environmental variation in LWT, QIX and QGD exists among different sires. The LWT, QIX and QGD can be altered by management changes only within the limits of the genetic potential of the animals, which in turn, can be further improved by breeding. A similar conclusion was made by Parkkonen et al. (2000), who showed that carcass quality of Finnish Ayrshire and Holstein-Friesian was significantly affected by genotype and environment interaction.

Genetic parameters

Table 5 shows the estimates of genetic parameters, with approximate standard errors, for meat characters. It has been observed from Table 5 that boiled meat tenderness (BMAS, BSFR and BPEN) and pH were negatively correlated (r_g and r_p) with LWT, QIX and QGD. The correlations between all other traits were positive. LWT positively correlated with QGD (0.29 and 0.56 for r_p and r_g, respectively) indicating that a greater LWT is associated

Table 4. Interaction effects of bull x location on meat characters in Hanwoo cattle

Effects[2]	Traits[1]						
	LWT (kg)	QIX	QGD	pH	BMAS (g/cm^2)	BSFR (g/cm^2)	BPEN (g/cm^2)
MS	1,401.14	3.01	2.25	0.01	39,700	2,809,186	2,754,714
LS	*	*	*	NS	NS	NS	NS

[1] LWT=Live weight; QIX=Quantity index; QGD=Quality grade; BMAS=Boiled meat mastication; BSFR=Boiled meat shear force; BPEN=Boiled meat penetration.

[2] MS=Mean square; LS=Level of significance; * p<0.05; NS=Non-significant.

Table 5. Heritabilities (±SE), phenotypic and genetic correlations (±SE) of meat characters in Hanwoo cattle[1]

Traits[2]	LWT	QIX	QGD	pH	BMAS	BSFR	BPEN
LWT	0.37±0.02	0.34±0.2	0.56±0.05	-0.68±0.07	-0.18±0.03	-0.46±0.02	-0.06±0.03
QIX	0.11±0.1	0.13±0.01	0.46±0.4	-0.31±0.03	-0.43±0.05	-0.35±0.04	-0.16±0.03
QGD	0.29±0.02	0.21±0.03	0.43±0.02	-0.35±0.02	-0.78±0.01	-0.77±0.06	-0.62±0.01
pH	-0.16±0.04	-0.07±0.03	-0.16±0.04	0.37±0.01	0.53±0.01	0.61±0.02	0.33±0.03
BMAS	-0.13±0.07	-0.09±0.1	-0.17±0.03	0.25±0.06	0.14±0.01	0.28±0.03	0.51±0.03
BSFR	-0.20±0.03	-0.13±0.1	-0.35±0.01	0.47±0.01	0.11±0.08	0.35±0.03	0.21±0.01
BPEN	-0.03±0.01	-0.06±0.2	-0.29±0.07	0.18±0.09	0.18±0.01	0.17±0.02	0.32±0.03

[1] Heritabilities on the diagonal, and phenotypic and genetic correlations below and above the diagonal, respectively.

[2] LWT=Live weight; QIX=Quantity index; QGD=Quality grade; BMAS=Boiled meat mastication; BSFR=Boiled meat shear force; BPEN=Boiled meat penetration.

with a higher scoring of QGD. This correlation is favorable for working towards the breeding goal of improving LWT and QGD. Ensminger (1987) noted that finished cattle with higher QGD usually carry more weight, and the lower grades are lighter, which supports the present findings. The phenotypic correlations were lower than the genetic correlations in the present study but they were in the same direction. Estimated heritabilities especially for QGD (0.43), LWT (0.37), pH (0.37), BSFR (0.35) and BPEN (0.32) were relatively high (Table 5). These indicate that in Hanwoo cattle a large genetic variability still remains, which may be used for the improvement of meat characteristics. However, Taylor (1977) noted the h^2 of beef cattle to be 50, 40 and 50 for LWT, QGD and meat tenderness, respectively. In Hereford and some other beef breeds, h^2 of carcass traits were found to be moderate (Lamb et al., 1990; Arnold et al., 1991; Gregory et al., 1994; Wheeler et al., 1996), which partially supports the present findings.

CONCLUSION

Significant variations between the progeny performances of individual sire groups in several meat characters - LWT, QIX, QGD, BMAS, BPEN - indicate the scope for sire selection to improve meat potential of Korean native cattle. However, there are variations in meat quality and quantity due to both genetic and environmental effects. As Hanwoo provides most of the beef in Korea, main concern should be on improving management in beef production. Positive genetic correlations between LWT and QGD suggest that sire selection for LWT does also lead to an increase in QGD.

REFERENCES

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

Baik, D. H., M. A. Hoque and H. S. Choe. 2002. Estimation of genetic and environmental parameters of carcass traits in Hanwoo (Korean Native Cattle) population. Asian-Aust. J. Anim. Sci. 15(11):1523-1526.

Baik, D. H., M. A. Hoque and H. K. Park. 2002. Correlation between tenderness and other carcass characteristics of Hanwoo (Korean Native) steers Asian-Aust. J. Anim. Sci. 15(12):1677-1679.

Becker, W. A. 1985. Manual of Quantitative Genetics. Fourth edition. Academic Enterprises, Pullman, Washington.

Bouton, P. E., F. D. Carroll, P. V. Harris and W. R. Shorthose. 1973. Influence of pH and fibre construction state upon factors affecting the tenderness of bovine muscle. J. Food Sci. 38: 404-407.

Ensminger, M. E. 1987. Marketing and slaughtering cattle and calves. In: Beef Cattle Science. Sixth edition. The Interstate Printers and Publishers, Inc. Danville, Illinois. 572-602.

Gregory, K. E., L. V. Cundiff, R. M. Koch, M. E. Dikeman and M. Koohmaraie. 1994. Breed effects, retained heterosis, and estimates of genetic and phenotypic parameters for carcass and meat traits of beef cattle. J. Anim. Sci. 72:1174-1183.

Kim, H. C., D. H. Lee, K. S. Seo, Y. M. Cho and Y. I. Park. 1998. Estimation of heritabilities and expected progeny differences for carcass traits in Hanwoo. Animal Genetics and Breeding 2(1):1-4.

Lamb, M. A., O. W. Robinson and M. W. Tess. 1990. Genetic parameters for carcass traits in Hereford bulls. J. Anim. Sci. 68:64-69.

NFCF (National Farmers' Cooperatives Federation of Korea). 2000. Progress report on grading of livestock products. Grading Office of Livestock Products. 214-215.

Parkkonen P., A. E. Liinamo and M. Ojala. 2000. Estimates of genetic parameters for carcass traits in Finnish Ayrshire and Holstein-Friesian. Livest. Prod. Sci. 64:203-213.

Robinson, D. L., M. Schneeberger, S. Sivaranjasingam, M. Ukkonen, S. A. Borwick, C. A. McDonald, B. Tier, K. Hammond and B. Sundstrom. 1990. Genetic evaluation for carcass traits in Australian beef cattle. Proc. Of 4th WCGPLP. Edinburgh, pp. 461-464.

SAS. 1991. Statistical Analysis System. SAS Institute, SAS Inc. Cary, USA.

Shin, O.Y. and Y. I. Park. 1990. Estimation of genetic parameters for body weights of Korean native cattle. Korean J. Anim. Sci. 32(6):315-317.

Son, S. K., D. H. Baik, H. S. Choi and K. J. Han. 1997. Estimation of heretabilities for body weights and measurements of Korean native cows in Hanwoo breeding regions. Korean J. Anim. Sci.

39(6):653-660.

Taylor, R. E. 1977. Genetic change through selection. In: Scientific Farm Animal Production. Fifth edition. 227-242.

Watanabe, A., C. C. Daley and C. Devine. 1996. The effects of the ultimate pH of meat on tenderness changes during aging. Meat Sci. 42:774-780.

Wheeler, T. L., L. V. Cundiff, R. M. Koch and J. D. Crouse. 1996. Carcass traits and longissimus palatability. J. Anim. Sci. 74: 1023-1035.