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Factors Affecting Birth and Weaning Weights in Korean Indigenous Breed Calves

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ABSTRACT

Background: Understanding the factors that affect calf growth performance can enhance productivity in the cattle industry. This study investigated the effects of breed and sex, the difference between the date of birth and the estimated due date (DBE, gestation length), birth seasons, dam parity and age on body weight at birth and weaning in calves of Korean indigenous cattle breeds. Additionally, the correlation between body weight and body measurements at weaning was assessed.

Methods: A total of 246 calves (Hanwoo, n=136; White Hanwoo, n=42; Chikso, n=41; and Heugu, n=27) born between January 2016 and June 2023 were used in this study. All calves were raised with their dams until weaning. Multiple linear regression (MLR) was employed to evaluate the effects of breed, sex, DBE, birth season, dam parity and dam age on birth and weaning weight. Correlation analysis was conducted to assess the relationship between body weight and body measurements at weaning.

Result: Breed, sex, DBE and birth season significantly affected both birth and weaning weights ($p<0.05$). Hanwoo calves were the heaviest at birth, followed by Heugu, Chikso and White Hanwoo; at weaning, the order was Hanwoo, White Hanwoo, Chikso and Heugu. Male calves were heavier than females at both stages ($p<0.05$). Calves born after the estimated due date were heavier at birth and weaning ($p<0.05$). Calves born in summer had higher birth weights, while those born in winter had higher weaning weights ($p<0.05$). Dam parity did not affect birth weight ($p=0.318$) but significantly influenced weaning weight ($p=0.028$), with higher parity associated with greater weaning weight. Birth weight was a significant predictor of weaning weight ($p<0.001$). Weaning weight showed strong positive correlations with chest girth ($r=0.939$), body length ($r=0.827$), withers height ($r=0.816$), rump height ($r=0.814$), pelvic width ($r=0.788$), rump width ($r=0.782$), chest width ($r=0.752$) and chest depth ($r=0.714$).

Key words: Calf growth rates, Cattle industry, Durbin-watson statistic, Hanwoo, Multiple linear regression.

INTRODUCTION

Cattle productivity is a crucial aspect of the sustainable cattle industry. Previous studies have demonstrated how cattle productivity can be improved through various aspects such as genetics, nutrition and meat science (Snelling *et al*., 2019; Luebbe *et al*., 2019; Andreo *et al*., 2019). The body weight of heifers is closely associated with their birth weight (Hurst *et al*., 2021). Cattle with increased growth rates in early life may calve earlier, produce more milk and can be raised at lower costs (Chester-Jones *et al*., 2017; Davis *et al*., 2011; Shamay *et al*., 2005). Therefore, understanding the factors that influence birth and weaning weights is imperative for optimizing management practices in the cattle industry.

Both genetic and nongenetic factors influence birth and weaning weights (Szabó *et al*., 2006; Riley *et al*., 2007; Rezende *et al*., 2020; Kim *et al*., 2025). Breeding is considered a primary factor affecting birth and weaning weights (Szabó *et al*., 2006; Rezende *et al*., 2020). Furthermore, cross-mating high-performance breeds is often used to improve productivity (Favero *et al*., 2019). Other factors, including the sex of calves and the reproductive characteristics of dams, such as age, parity and gestation length, also influence calf weight (Szabó *et al*., 2006; Riley *et al*., 2007; Rezende *et al*., 2020; Cho *et al*., 2021; Duncan *et al*., 2023). Moreover, environmental conditions, including birth season and rearing conditions, influence weight (Almeida *et al*., 2023). Although previous

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studies have reported significant effects of these factors on birth and weaning weights in calves, the results have not been consistent across studies, varying by factors such as region and breed. Therefore, these inconsistencies indicate the need for further investigations across diverse breeds and environmental conditions. In Korea, Hanwoo is the dominant beef cattle breed, representing the majority of domestic beef supply. According to recent reports, the national beef self-sufficiency rate was approximately 40-41% in 2023-2024 and Hanwoo beef constitutes a substantial portion of this production. This underscoring its critical role in the Korean cattle industry (Hanwoo Board, 2024; Lee *et al*., 2025). Nevertheless, other indigenous breeds such as White Hanwoo, Chikso and Heugu also represent valuable genetic resources that require further attention for conservation and utilization.

To the best of our knowledge, no comprehensive study has simultaneously addressed various factors affecting birth and weaning weights in Korean indigenous cattle (Hanwoo, White Hanwoo, Chikso and Heugu). We aimed to identify the effects of various factors on the birth and weaning weights of indigenous Korean cattle breeds by simultaneously analyzing multiple factors.

MATERIALS AND METHODS

Animals

A total of 246 indigenous Korean breed calves (Hanwoo, n=136; White Hanwoo, n=42; Chikso, n=41; Heugu, 27) used in this study were born between January 2016 and June 2023 and raised with their dams until weaning. The calves were clinically healthy from birth until weaning. Body measurements were performed on 167 calves (Hanwoo, n=89; White Hanwoo, n=28; Chikso, n=26; Heugu, n=24) between February 2018 and June 2023, when the calves were weaned. The animals suckled the teats of their dams for colostrum and milk, began to be fed concentrates and hay at 30 days of age and were weaned at 90 days of age. All calves were born and raised at the Animal Genetic Resources Research Center, National Institute of Animal Science (Hamyang, Republic of Korea). They were kept with their dams in individual pens until weaning and both calves and dams were maintained under a uniform management and feeding system. Clean water and mineral blocks were available ad libitum. The housing facilities were based on an open housing system designed to maintain proper ventilation, natural lighting and hygiene. The local climate is classified as temperate and seasonal changes were managed through appropriate ventilation and water supply adjustments. There was no variation between farms or management practices, ensuring data homogeneity.

Data collection

We collected data related to the calves, including breed (Hanwoo, White Hanwoo, Chikso and Heugu) sex, the difference between the date of birth and estimated due date (DBE), birth seasons, age and parity of their dam, birth weight and body measurements at 90 days of age. The body measurements included body weight, withers height, rump height, body length, chest depth, chest width, rump length, rump width, pelvic width, hipbone width and chest girth. The calving seasons were grouped as spring (March to May), summer (June to August), autumn (September to November), or winter (December to February).

Statistical analyses

Statistical analyses were performed using the SPSS software (SPSS 27.0, IBM-SPSS INC, Chicago, IL, USA). We performed multiple linear regression (MLR) analyses to assess the effects of breed, sex, DBE, dam age, dam parity and birth season on birth weight. In addition, we evaluated the effects of birth weight including those on birth weight at weaning. A dummy conversion was applied to breed, sex and birth season.

The fitted regression equation is as follows:

$$\text{Body weight} = (\text{Constant}) + b_1x_1 + b_2x_2 \ldots + b_nx_n$$

Where the regression coefficients (constants) b_1, b_2,..., b_n represent the independent contributions of each independent variable x_1, x_2,... x_n for evaluating the effects of these factors on body weight. Statistical significance was set at $p<0.05$. Multicollinearity among independent variables was examined using tolerance and variance inflation factors to conduct the MLR analysis. Tolerance above 0.1 and a variance inflation factor (VIF) of less than 10 indicate no multicollinearity. The Durbin-Watson (D-W) statistic ranged from 1 to 3, confirming that there was no autocorrelation between errors.

Pearson's correlation test was used to determine the correlations between body measurements at weaning. Pearson's correlation coefficient was represented as $r \geq 0.7$, strong correlation; $0.5 \leq r < 0.7$, moderate correlation; $0.3 \leq r < 0.5$, weak correlation; and $r < 0.3$, no correlation.

RESULTS AND DISCUSSION

Effects of breed, sex, DBE, birth seasons, age and parity of dam on birth weight

The results from the MLR model were significant in identifying the effects of breed, sex, DBE, birth season, age and parity of the dam on birth weight (F=14.166, $p<0.001$) (Table 1). The explanatory power of the MLR model was 37.6% (R^2=0.376, $_{adj}R^2$=0.350). The tolerance, VIF and D–W statistic results indicated no multicollinearity and no autocorrelation between the errors. Significance testing of the regression coefficients revealed that breed, sex, DBE and birth in summer influenced birth weight ($p<0.05$). White Hanwoo breed (β=-0.404) had the largest impact, followed by Chikso breed (β=-0.347), DBE (β=0.25), sex (β=0.229), Heugu (β=-0.118) and birth in summer (β=0.117). In terms of breed, White Hanwoo (β=-0.404), Chikso (β=-0.347) and Heugu (β=-0.118) calves were born with less weight than Hanwoo calves. Additionally, calves were born later than the estimated due date in summer and a male calf had considerable weight at birth.

Effects of breed, sex, DBE, birth season, age and parity of dam and birth weight on weaning weight

The MLR model was used to identify the effects of breed, sex, DBE, birth season, age and parity of dam and birth weight was statistically significant (F=14.209, p<0.001) (Table 2). The MLR model explanatory power of 50.2% (R^2=0.502, $_{adj}R^2$=0.467). Multicollinearity and autocorrelation between errors were not identified. Breed, sex, DBE, winter birth, dam parity and birth weight significantly influenced weaning weight (p<0.05). Birth weight (β=0.413) had the largest impact, followed by dam parity (β=0.312), Heugu (β=-0.283), Chikso (β=-0.274), birth in winter (β=0.27), White Hanwoo (β=-0.248), DBE (β=0.151) and sex (β=0.147). Calves with heavy weights at birth weighed much more at weaning. Furthermore, high-parity cows delivered and raised heavier calves. Hanwoo weighed more at weaning than White Hanwoo, Chikso and Heugu. Calves that were born in winter, later than the estimated due date and male calves weighed more at weaning.

Correlation between body measurements at weaning

We investigated the correlations between body weight, withers height, rump height, body length, chest depth, chest width, rump length, rump width, pelvic width, hipbone width and chest girth at weaning (Table 3). Body weight at weaning strongly correlated with chest girth (r=0.939), body

Table 1: Effects of breed, sex, birth date, birth season, dam parity and age on birth weight of indigenous Korean breed calves.

Variable	B	Standard error	β	t	*p* value	Tolerance	VIF
(Constant)	25.85	0.696		37.118	<0.001		
Breed (Hanwoo=reference)							
White Hanwoo	-3.957	0.539	-0.404	-7.338	<0.001	0.876	1.141
Chikso	-3.437	0.555	-0.347	-6.192	<0.001	0.843	1.186
Heugu	-1.394	0.7	-0.118	-1.99	0.048	0.753	1.328
Sex (Female=reference)							
Male	1.685	0.388	0.229	4.342	<0.001	0.958	1.043
DBE	0.133	0.029	0.25	4.572	<0.001	0.886	1.128
Season (Spring=reference)							
Summer	1.253	0.622	0.117	2.014	0.045	0.783	1.278
Autumn	0.75	0.449	0.099	1.669	0.096	0.748	1.336
Winter	-0.55	0.696	-0.047	-0.79	0.43	0.737	1.356
Parity of dam	0.371	0.371	0.119	1.001	0.318	0.189	5.301
Age of dam	0.094	0.212	0.052	0.442	0.659	0.188	5.317
F=14.166(p<0.001), R^2=0.376, $_{adj}R^2$=0.350, D–W=1.586							

Abbreviations: VIF, Variance inflation factor; DBE, Difference between the date of birth and estimated due date; D-W, Durbin-Watson.

Table 2: Effects of breed, sex, birth date, birth season, dam parity and age and birth weight on weaning weight of indigenous Korean breed calves.

Variable	B	Standard error	β	t	*p* value	Tolerance	VIF
(Constant)	32.799	12.065		2.719	0.007		
Breed (Hanwoo=reference)							
White Hanwoo	-15.383	4.127	-0.248	-3.728	<0.001	0.725	1.38
Chikso	-17.527	4.264	-0.274	-4.11	<0.001	0.721	1.388
Heugu	-18.649	4.505	-0.283	-4.14	<0.001	0.69	1.45
Sex (Female=reference)							
Male	6.845	2.813	0.147	2.433	0.016	0.88	1.137
DBE	0.482	0.202	0.151	2.386	0.018	0.807	1.239
Season (Spring=reference)							
Summer	-1.488	4.494	-0.021	-0.331	0.741	0.809	1.236
Autumn	5.448	3.152	0.111	1.728	0.086	0.778	1.286
Winter	18.46	4.561	0.27	4.047	<0.001	0.724	1.382
Parity of dam	5.798	2.613	0.312	2.219	0.028	0.163	6.152
Age of dam	-2.149	1.613	-0.187	-1.332	0.185	0.163	6.142
Birth weight, kg	2.478	0.422	0.413	5.877	<0.001	0.65	1.538
F=14.209(p<0.001), R^2=0.502, $_{adj}R^2$=0.467, D–W=1.356							

Abbreviations: VIF, Variance inflation factor; DBE, Difference between the date of birth and estimated due date; D-W, Durbin-watson.

length (r=0.827), withers height (r=0.816), rump height (r=0.814), pelvic width (r=0.788), rump width (r=0.782), chest width (r=0.752) and chest depth (r=0.714). The correlations between body weight at weaning and rump length (r=0.610) and hipbone width (r=0.596) were moderate (p<0.001). Strong correlations were identified between withers and rump heights (r=0.998) and between rump and pelvic width (r=0.879).

In the present study, breed, sex, DBE and season (summer) were associated with birth weight in indigenous Korean cattle. Furthermore, breed, sex, DBE, season (winter), dam parity and birth weight were associated with their weaning weight, which was strongly correlated with chest girth, body length, withers height, rump height, pelvic width, rump width, chest width and depth.

The findings of the current study are consistent with those of previous studies that identified the effects of breed, sex and DBE on birth and weaning weights in indigenous Korean cattle breeds. Choi *et al*. (2015) reported that breed affects birth and weaning weight; this study compared White Hanwoo, Chikso and Heugu, except for most indigenous Korean cattle breeds, Hanwoo. The current study is the first to report that Hanwoo cattle are heavier than other Korean indigenous cattle breeds at birth and weaning. Moreover, as in a previous study, male calves were heavier than female calves at birth and at weaning (Kayastha *et al*., 2008; Park *et al*., 2022). Gestational length is associated with weight at birth and weaning (Hwang *et al*., 2008, Coleman *et al*., 2021).

Although the effects of birth season on birth and weaning weights are controversial owing to various factors, such as rearing and pasture conditions, several studies have verified the effects of birth season in cattle (Szabó *et al*., 2006; Wakchaure and Meena, 2010; Cho *et al*., 2021; Park *et al*., 2022). In this study, we observed that calves born in summer were heavier at birth and those born in winter were heavier at weaning. One of the possible explanations for seasonal effects may be the fluctuation in cattle hormones, such as insulin and glucagon. Insulin concentrations in dairy cattle are higher in winter than in summer (Herbein *et al*., 1985; De Rensis *et al*., 2002; Denbow *et al*., 1986), which leads to elevated glucose levels in summer. Insulin promotes anabolic processes in the muscles and liver, thereby enhancing carbohydrate and lipid metabolism (Dimitriadis *et al*., 2011). Maternal glucose concentration was positively correlated with neonatal birth weight (Breschi *et al*., 1993). Thus, low insulin concentrations in summer that lead to high glucose concentrations in dams might result in heavy calves at birth, whereas high insulin levels in winter may contribute to heavier weaning weights by promoting anabolism in calves. Although further mechanistic studies are needed, our results suggest that seasonal metabolic variations may underlie the effects of birth season.

The parity of dams has also been reported to influence calf growth. Several studies have shown that higher dam parity positively affects calf body weight at birth and weaning (Kertz *et al*., 1997; El-Nazeir *et al*., 2015; Habtamu *et al*., 2012). The body weights of Hanwoo steer calves at birth and weaning were positively associated with the parity of dam (Lee *et al*., 2024). However, the effect of dam parity on calves' birth weight remains controversial. Willis and Wilson (1974) reported that dam parity did not influence birth weight. In this study, the birth weight of calves was not associated with the parity of the dams, although calves born to cows with high parity had a much higher weaning weight. These results may be due to the nourishing experiences of the dams. For instance, a study on sheep (Lv *et al*., 2015) revealed that lamb birth weight was not associated with ewe parity, but weaning weight was associated with the experience and maternal behavior of the ewes. Multiparous ewes exhibited more positive maternal behaviors towards their lambs, such as increase grooming, better udder acceptance, low-pitched bleats and lower udder refusal. The positive association observed between lamb weight and their ewe parity may also apply to cattle. The parity of cows might influence the nourishing behavior towards their offspring; high parity cows have

Table 3: Correlation between weaning weights and body measurement.

	Weaning weight	Withers height	Rump height	Body length	Chest depth	Chest width	Rump length	Rump width	Pelvic width	Hipbone width	Chest girth
Weaning weight	1	0.816***	0.814***	0.827***	0.714***	0.752***	0.610***	0.782***	0.788***	0.596***	0.939***
Withers height		1	0.998***	0.871***	0.598***	0.628***	0.608***	0.670***	0.659***	0.572***	0.762***
Rump height			1	0.871***	0.588***	0.621***	0.604***	0.659***	0.652***	0.575***	0.759***
Body length				1	0.567***	0.691***	0.537***	0.666***	0.681***	0.538***	0.778***
Chest depth					1	0.639***	0.551***	0.720***	0.696***	0.554***	0.719***
Chest width						1	0.584***	0.817***	0.796***	0.476***	0.724***
Rump length							1	0.645***	0.636***	0.460***	0.578***
Rump width								1	0.879***	0.476***	0.754***
Pelvic width									1	0.535***	0.735***
Hipbone width										1	0.581***
Chest girth											1

***p<0.001.

improved maternal behavior, leading to heavy weights at weaning. The results of the present study on dam age support our estimation. Overall, these findings suggest that the greater weaning weights observed in calves from higher parity dams may be attributed to the more practiced nourishing experiences of the dams rather than simply an increase in the age of the dam.

The initial birth weight strongly influences growth performance. Previous studies demonstrated that calves with higher birth weights had grater weaning weights and higher pre-weaning average daily gain (Rahnefeld *et al*., 1980). Calves with specific haplotype in locus of the bovine growth hormone gene had lower body weights at birth and 30 days of age (Ishida *et al*., 2020). Organ development also plays a role, as calves with heavier birth weights had heavier livers, supporting their greater metabolic capacity (Jacobsen *et al*., 2000). Together, these findings indicate that higher birth weights may enhance growth potential through both genetic and nutritional mechanisms, which aligns with the results of the present study. Future studies incorporating genomic information may further clarify the genetic basis of these growth traits.

Previous study that examined different cattle breed, such as Brahman and Bali confirmed positive correlations between various body measurements and body weight. These studies reported that the chest girth had the highest correlation with body weight (Kamprasert *et al*., 2019; Gunawan and Jakaria, 2010). The present results demonstrated the same tendency in Hanwoo cattle.

A limitation of our study was that it was conducted on a single farm; therefore, we could not include diverse environmental rearing conditions. However, this study was conducted on identical farms over a long period, which allowed us to control for other factors affecting calf weight, such as staff, feed and management. Future studies should expand to multiple farms and regions to validate our findings across diverse environments and production systems. Moreover, our findings have practical implications: understanding the interplay of breed, parity and seasonal effects can help optimize calf management, improve productivity and contribute to the conservation and sustainable use of Korean indigenous cattle breeds.

CONCLUSION

To the best of our knowledge, this is the first study to simultaneously evaluate the effects of multiple factors on birth and weaning weights across all indigenous Korean cattle breeds, including Hanwoo, White Hanwoo, Chikso and Heugu. The results offer valuable insights into breed specific growth characteristics and can serve as a foundation for developing improved early life management strategies for indigenous Korean cattle.

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Disclaimers

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Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the Institutional Animal Care and Use Committee of the National Institute of Animal Science (approval number: NIAS-20230609), Republic of Korea.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

Almeida, J.V.N.D., Marques, L.R., Oliveira, A.C., Paim, T.D.P., Marques, T.C. and Leão, K.M. (2023). Environmental and physiological measures in the neonatal period as indicators of growth and puberty of Holstein heifers. *Ciencia Rural*. **53(12):** e20220528.

Andreo, N., Bridi, A.M., Peres, L.M., Dos Santos, É.R., Barro, A.G., Gonçalves, J.R.S., Bonfa, H.C. and Pires, A.V. (2019). Carcass characteristics and meat quality of Nellore bulls submitted to different nutritional strategies during cow-calf and stocker phase. *Animal.* **13:** 1544-1551.

Breschi, M.C., Seghieri, G., Bartolomei, G., Gironi, A., Baldi, S. and Ferrannini, E. (1993). Relation of birthweight to maternal plasma glucose and insulin concentrations during normal pregnancy. *Diabetologia*. **36:** 1315-1321.

Chester-Jones, H., Heins, B. J, Ziegler, D., Schimek, D., Schuling, S., Ziegler, B., de Ondarza, M.B., Sniffen, C.J. and Broadwater, N. (2017). Relationships between early-life growth, intake and birth season with first-lactation performance of Holstein dairy cows. *Journal of Dairy Science.* **100:** 3697-3704.

Cho, K., Song, Y., Yeo, J.M., Park, J.K., Kim, D.W., Roh S.H., Seong, P. and Lee, W.Y. (2021). Analysis of seasonal effect on Korean native cattle (Hanwoo) birth weight. *Journal of Animal Science and Technology*. **63:** 759-765.

Choi, S.B., Cho, C.Y., Kim, J.H., Byun, M.J., Suh, S.W., Ko, Y.G., Cho, Y.M. and Kim, Y.S. (2015). The performance of growth traits in Korean domestic animal genetic resources; Chikso, Heugu and white Hanwoo. *Journal of the Korean Society of International Agriculture*. **27:** 398-404.

Coleman, L., Back, P., Blair, H., Lopez-Villalobos, N. and Hickson, R. (2021). Sire effects on birth weight, gestation length and pre-weaning growth of beef-cross-dairy calves: A case study in New Zealand. *Dairy*. **2:** 385-395.

Davis, R.L.E., Vandehaar, M.J., Wolf, C.A., Liesman, J.S., Chapin, L.T. and Weber Nielsen, M.S. (2011). Effect of intensified feeding of heifer calves on growth, pubertal age, calving age, milk yield and economics. *Journal of Dairy Science.* **94:** 3554-3567.

De Rensis, F., Marconi, P., Capelli, T., Gatti, F., Facciolongo, F., Franzini, S. and Scaramuzzi, R.J. (2002). Fertility in postpartum dairy cows in winter or summer following estrus synchronization and fixed time AI after the induction of an LH surge with GnRH or hCG. *Theriogenology*. **58:** 1675-1687.

Denbow, C.J., Perera, K.S., Gwazdauskas, F.C., Akers, R.M., Pearson, R.E. and McGilliard, M.L. (1986). Effect of season and stage of lactation on plasma insulin and glucose following glucose injection in Holstein cattle. *Journal of Dairy Science*. **69:** 211-216.

Dimitriadis, G., Mitrou, P., Lambadiari, V., Maratou, E. and Raptis, S.A. (2011). Insulin effects in muscle and adipose tissue. *Diabetes Research and Clinical Practice*. **93(1):** 52-59.

Duncan, N.B., Stoecklein, K.S., Foote, A.P. and Meyer, A.M. (2023). Dam parity affects fetal growth, placental size and neonatal metabolism in spring-born beef calves. *Journal of Animal Science*. **101:** skac399.

El-Nazeir, B., Mohammed, A., El-Khidir, O. and Atta, M. (2015). Influence of nongenetic factors on birth and weaning weights of Friesian crossbred calves in the Sudan.

Favero, R., Menezes, G.R.O., Torres, R.A.A., Silva, L.O.C., Bonin, M.N., Feijó, G.L.D., Altrak, G., Niwa, M.V.G., Kazama, R., Mizubuti, I.Y. and Gomes, R.C. (2019). Crossbreeding applied to systems of beef cattle production to improve performance traits and carcass quality. *Animal.* **13:** 2679-2686.

Gunawan, A. and Jakaria, J. (2010). Application of linear body measurements for predicting weaning and yearling weight of Bali cattle. *Animal Production*. **12:** 163-168.

Habtamu, A., Solomon, A. and Yoseph, M. (2012). Influence of non-genetic factors on growth traits of Horro (Zebu) and their crosses with Holstein Friesian and Jersey cattle. *International Journal of Livestock Production*. **3:** 72-77.

Hanwoo Board. (2024). Beef supply and demand statistics. Hanwoo Board. Available at: https://m.hanwooboard.or.kr/pages/statistics/industry/tab2.php

Herbein, J.H., Aiello, R.J., Eckler, L.I., Pearson, R.E. and Akers, R.M. (1985). Glucagon, insulin, growth hormone and glucose concentrations in blood plasma of lactating dairy cows. *Journal of Dairy Science*. **68:** 320-325.

Hurst, T.S., Lopez-Villalobos, N. and Boerman, J.P. (2021). Predictive equations for early-life indicators of future body weight in Holstein dairy heifers. *Journal of Dairy Science*. **104:** 736-749.

Hwang, J.M., Choi, J.G., Kim, H.C., Choy, Y.H., Kim, S., Lee, C., *et al.* (2008). Genetic relationship of gestation length with birth and weaning weight in Hanwoo (Bos taurus coreanae). *Asian Australas J. Anim. Sci.* **21:** 633-639.

Ishida, T., Umebayashi, A., Tsuruta, S., Akashi, R. and Harada, H. (2020). Polymorphisms in growth hormone gene and their associations with calf weight in Japanese Black cattle. *Animal Science Journal*. **81:** 623-629.

Jacobsen, H., Schmidt, M., Holm, P., Sangild, P.T., Vajta, G., Greve, T. and Callesen, H. (2000). Body dimensions and birth and organ weights of calves derived from *in vitro* produced embryos cultured with or without serum and oviduct epithelium cells. *Theriogenology.* **53:** 1761-1769.

Kamprasert, N., Duijvesteijn, N. and Van der Werf, J.H.J. (2019). Estimation of genetic parameters for BW and body measurements in Brahman cattle. *Animal.* **13:** 1576-1582.

Kayastha, R.B., Zaman, G. and Goswami, R.N. (2008). Studies on the birth weight of indigenous cattle of assam. *Indian J. Anim. Res.* **42(3):** 230-231.

Kertz, A.F., Reutzel, L.F., Barton, B.A. and Ely, R.L. (1997). Body weight, body condition score and wither height of prepartum Holstein cows and birth weight and sex of calves by parity: A database and summary. *Journal of Dairy Science*. **80:** 525-529.

Kim, D.H., Jung, M., Lee, J., Jeon, E., Park, J., Ryu, G. and Ha, S. (2025). Comparison of influencing factors on birth weight between Holstein and Jersey calves. *Indian J. Anim. Res*. pp. 1-4. doi: 10.18805/IJAR.BF-1988.

Lee, S.H., Kim, N.K., Park, E.W., Kim, T.H. and Lim, D. (2025). A comprehensive review of the history and breed characteristics of Hanwoo cattle: From domestication to genomic selection. *Korean Journal for Food Science of Animal Resources*. **45(5):** 1251-1267.

Lee, S.H., Shin, J.S., Cho, S.M., Son, G.H., Lee, E.K., Kim, N.O. and Park, B.K. (2024). Effects of dam's parity on growth performance, carcass characteristics and economic efficacy of Hanwoo steers. *Korea Academic-Industrial cooperation Society.* **25:** 70-78.

Luebbe, K.M., Stalker, L.A., Klopfenstein, T.J. and Funston, R.N. (2019). Influence of weaning date and late gestation supplementation on beef system productivity I: Animal performance. *Translational Animal Science*. **3:** 1492-1501.

Lv, S.J., Yang, Y., Dwyer, C.M. and Li, F.K. (2015). Pen size and parity effects on maternal behaviour of Small-tail Han sheep. *Animal*. **9:** 1195-1202.

Park, J.K., Cho, K., Yeo, J.M., Kim, D.W., Seong, P. and Lee, W.Y. (2022). Effect of birth and lactation season on the growth of Korean Hanwoo calves. *Journal of Animal Reproduction and Biotechnology.* **37:** 298-302.

Rahnefeld, G.W., Parker, R.J., Yodseranee, S. and Stringam, E.W. (1980). Influence of body weight and changes in body weight of the cow on preweaning traits of the calf. *Canadian Journal of Animal Science*. **60:** 599-607.

Rezende, E.V., Reis, I.J., Campos, C.C. and Santos, R.M. (2020). Influence of gestation length, seasonality and calf sex on birth weight and placental retention in crossbred dairy cows. *Ciência Animal Brasileira*. pp. 21.

Riley, D.G., Chase, C.C., Coleman, S.W. and Olson, T.A. (2007). Evaluation of birth and weaning traits of Romosinuano calves as purebreds and crosses with Brahman and Angus. *Journal of Animal Science.* **85:** 289-298.

Szabó, F., Nagy, L., Dákay, I., Márton, D., Török, M. and Bene, S. (2006). Effects of breed, age of dam, birth year, birth season and sex on weaning weight of beef calves. *Livestock Science.* **103:** 181-185.

Shamay, A., Werner, D., Moallem, U., Barash, H. and Bruckental, I. (2005). Effect of nursing management and skeletal size at weaning on puberty, skeletal growth rate and milk production during first lactation of dairy heifers. *Journal of Dairy Science*. **88:** 1460-1469.

Snelling, W.M., Kuehn, L.A., Thallman, R.M., Bennett, G.L. and Golden, B.L. (2019). Genetic correlations among weight and cumulative productivity of crossbred beef cows. *Journal of Animal Science*. **97:** 63-77.

Wakchaure, R.S. and Meena, R. (2010). Factors affecting, birth weight, age and weight at first calving in Sahiwal cattle. *Indian J. Anim. Res*. **44(3):** 173-177.

Willis, M.B. and Wilson, A. (1974). Factors affecting birth weight of Santa Gertrudis calves. *Animal Science.* **18:** 231-236.