J Anim Reprod Biotechnol 2024;39:121-130
pISSN: 2671-4639 • eISSN: 2671-4663
https://doi.org/10.12750/JARB.39.2.121

Original Article

JARB
Journal of Animal Reproduction and Biotechnology
Check for updates

Analyzing environmental factors influencing the gestation length and birth weight of Hanwoo cattle

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Received May 17, 2024
Revised June 10, 2024
Accepted June 11, 2024

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ABSTRACT

Background: This study focused on reproductive traits in Hanwoo cattle, specifically the environmental factors affecting gestation length and birth weight.

Methods: The records of 1,540 cows calved at the Hanwoo Research Institute from 2015 to 2023 were examined. This study analyzed two populations, line-breeding Hanwoo (LBH) and general Hanwoo (GH), with all cows undergoing estrus synchronization and artificial insemination. The R software was used to compare the differences between the two populations and analyze the environmental factors affecting each trait.

Results: The results showed that the average gestation length for LBH was 283.28 ± 5.93 days, which was significantly shorter than that of the GH, which had an average of 285.63 ± 6.21 days ($p < 0.001$). The average birth weight of LBH calves was 25.10 ± 3.69 kg, significantly lighter than GH calves, which weighed 27.26 ± 4.11 kg on average ($p < 0.001$). Analysis of environmental factors revealed significant differences in the gestation length of LBH based on dam parity, year, and season of calving. However, no significant differences were observed based on calf sex. For LBH, birth weight showed significant differences based on dam parity, year of calving, and sex of the calf, but not the season of calving. In GH, gestation length varied with dam parity and calving season, but not with calving year or calf sex. The GH birth weight showed differences based on dam parity, year of calving, and calf sex, but not the season of calving.

Conclusions: Reproductive traits in the Hanwoo cattle industry are economically vital but are heavily influenced by environmental factors due to their low heritability. An accurate evaluation of the genetic potential of these traits requires an analysis of the environmental factors affecting them. The results of this study serve as foundational data for predicting the potential for genetic improvement in the gestation length and birth weight of Hanwoo cattle.

Keywords: birth weight, gestation length, Hanwoo, reproductive trait

INTRODUCTION

Interest in improving the genetic capabilities of cows in Hanwoo cattle (Korean native cattle) continues to grow. This is because the abilities of both the sire and dam are important for producing superior calves. In Korea, a Hanwoo cattle improvement program is conducted at the national level, leading to the selection and numbering of Hanwoo proven bulls (Korean Proven Bull's Number, KPN). Semen produced by Hanwoo proven bulls is distributed to farms, facilitating the enhancement of Hanwoo cattle through artificial insemination (AI) and contributing to increased income for farms (Kim et al., 2017; Choi et al., 2018). Therefore, farms must select superior cows for breeding to produce calves with excellent genetic capabilities.

Among the various capabilities of cows, reproductive ability is a crucial economic trait directly linked to farm income. This study investigated and analyzed the gestation length of dams and calf birth weight among the various reproductive traits of Hanwoo cattle. Gestation length in cattle is defined as the duration from conception to birth of the calf. Typically, a shorter gestation length is linked to a lighter birth weight, easier calving, and enhanced subsequent reproductive performance in dams. Additionally, calves born after a shorter gestation length tend to have longer post-birth growth periods, which can lead to heavier weaning weights (BREEDPLAN, 2024).

The ranges for gestation length and birth weight in Hanwoo cattle, as well as the environmental factors affecting these traits, such as the region, farm, parity of the dam, timing of calving (year and season of calving), sex of the calf, and sire, have been reported to vary significantly depending on the time of investigation and experimental subjects. Lopez et al. (2019) noted that calving-related traits in Hanwoo cattle, including gestation length, exhibited low heritabilities ranging from 0.03 to 0.13. However, they emphasized that the economic importance of these traits should not be overlooked, and that through improved management techniques, it is necessary to develop these traits to reach optimal levels.

Similar to all other traits, reproductive traits are determined by complex interactions between genetic and environmental factors, with a particularly significant influence of external environmental conditions. Therefore, understanding the environmental factors affecting reproductive traits is essential before efforts to genetically improve these traits can begin.

This study investigated the gestation length and birth weight of two populations at the Hanwoo Research Institute (HRI) of the National Institute of Animal Science (NIAS) and analyzed the environmental factors influencing these traits. Hanwoo cattle are known for their distinct genetic characteristics and pure bloodline, distinguishable from exotic beef species, as outlined in the Livestock Industry Act. To preserve these qualities, the Hanwoo proven bulls are selected from a diverse range of pedigrees, taking into consideration the lineage of the sire and maternal grandsire to maintain genetic diversity within the entire Hanwoo population and to prevent inbreeding depression (Jin et al., 2023). Additionally, the HRI has been maintaining a line-breeding population using its own non-KPN sires to enhance the genetic diversity of Hanwoo cattle. From this line-breeding population of the HRI, two outstanding animals are selected annually as candidate bulls, contributing to the preservation of genetic diversity in Hanwoo cattle (MAFRA, 2024). The HRI thus maintains two distinct populations: the line-breeding Hanwoo (LBH), a line-breeding population that has been maintained since 2009 at HRI using proprietary bulls selected, and the general Hanwoo (GH), a population formed using Hanwoo proven bulls. A previous study compared the two populations based on 11 microsatellite markers, showing genetic differences between the populations (Jin et al., 2023).

In the present study, we investigated the gestation lengths and birth weights of two populations of Hanwoo cattle raised under the same feeding and gestational environments. Our objective was to analyze the environmental effects on these reproductive traits and to use the data from these populations to predict the potential for genetic improvement of gestation length and birth weight of Hanwoo cattle. These insights are crucial for understanding how external conditions influence reproductive outcomes and for informing future breeding strategies.

MATERIALS AND METHODS

Animals

In this study, we analyzed the calving records of 1,540 Hanwoo cows that delivered normal singletons between 2015 and 2023 at the HRI of NIAS. The dataset included the records of 910 LBH and 630 GH cows. LBH is a line-breeding population that has been maintained at the HRI since 2009 using selected proprietary bulls, and GH is a population formed using Hanwoo proven bulls. All experimental procedures were conducted according to national and institutional guidelines and were approved by the Ethical Committee of the NIAS, Republic of Korea (approval number: 2020-449).

Synchronization of estrus and AI

All individuals were inseminated through AI following estrus synchronization. Regardless of the estrous cycle stage, each cow was fitted with a Controlled Internal Drug Release (CIDR) device containing 1.9 g of progesterone (CIDR; Zoetis, New Zealand) inserted into the vagina at 09:00. Concurrently, 2 mL (100 mcg gonadorelin acetate/mL) of gonadotropin-releasing hormone (GnRH; Fertagyl GmbH, Germany) was administered via injection into the neck muscles. Seven days later, the CIDR device was removed at 09:00, followed by the administration of 5 mL (5 mg dinoprost tromethamine/mL) of prostaglandin F2α (PGF2a; Lutalyse, Zoetis, Belgium).

Two days after the removal of the CIDR, a further 2 mL of GnRH was injected to induce ovulation. AI procedures were performed at 18:00 on the day of the GnRH injection (first AI) and again at 09:00 the following morning (second AI). The semen used for AI contained an average of 18 million sperm per 0.5 mL straw. Before the AI procedure, semen straws were thawed in water at 37℃ for 40 s and loaded into an AI gun fitted with a protective sheath. Skilled technicians performed the insemination. Further details regarding estrus synchronization and AI have been described by Kang et al. (2024).

Trait investigation

The gestation length was calculated from the second AI date to the day of calving. Birth weight was measured immediately after birth (within 8 h). The final analysis included gestation lengths of 260 to 310 days and calf birth weights ranging from 17 to 38 kg. The number of cows used per parity for calving is shown in Table 1.

For the comparative analysis between various groups, cows were classified into three groups based on parity: Group A included heifers and cows; Group B comprised 1st, 2nd, 3rd, and higher parity cows; and Group C consisted of 1st, 2nd, 3rd, and 4th or higher parity cows.

The calving seasons were classified as follows: March to May (spring); June to August (summer); September to November (fall); and December to February (winter). Although Group A is categorized into four seasons, AI at HRI specifically targets calve births in spring and fall. Due to the unequal distribution of samples across the seasons, Group B was designated for comparing the spring and fall seasons.

Table 1. Number of data used for analysis by parity in two Hanwoo populations

Parity	LBH (N)	GH (N)
1	286	185
2	167	131
3	150	111
4 ≤	307	203
Total	910	630

LBH, line-breeding Hanwoo; GH, general Hanwoo; N, number of animals.

Statistical analysis

R software (R Foundation for Statistical Computing, Vienna, Austria) was used for data preprocessing and variance analysis. The data preprocessing steps included handling missing values and detecting and correcting outliers.

The primary objective of this study was to evaluate the differences in gestation length and birth weight between LBH and GH cattle, as well as the differences between groups according to various environmental factors. For this purpose, linear models were constructed, and variance analysis (ANOVA) was conducted to quantitatively assess the differences between groups.

To assess whether the differences between groups were statistically significant, Duncan's new multiple range test, which uses the mean square error, was conducted. This test was used to identify groups with statistically significant differences and to analyze the specific differences between the group means.

RESULTS

Average capabilities of the two populations

Significant differences were observed in both gestation length and birth weight between the LBH and GH populations (Table 2). The average gestation length for LBH was 283.28 ± 5.93 days, while for GH it was 285.63 ± 6.21 days, with the LBH having a significantly shorter gestation length ($p < 0.001$). The average birth weight was 25.10 ± 3.69 kg for LBH and 27.26 ± 4.11 kg for GH, showing significant differences ($p < 0.001$). Differences in the average capabilities between the two populations were analyzed by differentiating the effects of each environmental factor.

Table 2. Statistical analysis of gestation length of dams and birth weight of calves in two Hanwoo populations

Population	N	GL (day)					BW (kg)				
		Mean	SD	MIN	MAX	*p*	Mean	SD	MIN	MAX	*p*
LBH	910	283.28[b]	5.93	261	309	< 0.001	25.10[b]	3.69	17	38	< 0.001
GH	630	285.63[a]	6.21	264	310		27.26[a]	4.11	17	38	

[a,b]Values in columns denoted by different superscript lower-case letters differ significantly among groups ($p < 0.001$). GL, gestation length; BW, birth weight; LBH, line-breeding Hanwoo; GH, general Hanwoo; N, number of animals; SD, standard deviation; MIN, minimum; MAX, maximum.

Table 3. Effect of parity of dams on gestation length and birth weight of calves in two Hanwoo populations

Variation			LBH					GH				
Group		Parity	N	Mean ± SD	MIN	MAX	*p*	N	Mean ± SD	MIN	MAX	*p*
GL (day)	A	1	286	282.65 ± 6.07[b]	261	302	0.03	185	285.01 ± 6.33	264	310	0.105
		2 ≤	624	283.56 ± 5.85[a]	263	309		445	285.89 ± 6.15	264	308	
	B	1, 2	453	282.66 ± 6.27[b]	261	305	0.002	316	285.12 ± 6.25[b]	264	310	0.041
		3 ≤	457	283.89 ± 5.53[a]	266	309		314	286.13 ± 6.14[a]	264	308	
	C	1	286	282.65 ± 6.07[b]	261	302	0.004	185	285.01 ± 6.33[b]	264	310	0.027
		2	167	282.67 ± 6.60[b]	263	305		131	285.29 ± 6.15[b]	264	306	
		3	150	283.18 ± 5.61[a,b]	266	302		111	285.09 ± 5.46[b]	271	308	
		4 ≤	307	284.24 ± 5.46[a]	267	309		203	286.70 ± 6.42[a]	264	307	
BW (kg)	A	1	286	24.49 ± 3.67[b]	17	34	< 0.001	185	26.42 ± 4.07[b]	17	37	< 0.001
		2 ≤	624	25.37 ± 3.68[a]	17	38		445	27.61 ± 4.07[a]	17	38	
	B	1, 2	453	24.75 ± 3.74[b]	17	38	0.005	316	26.34 ± 3.99[b]	17	38	< 0.001
		3 ≤	457	25.44 ± 3.62[a]	17	37		314	28.18 ± 4.02[a]	18	37	
	C	1	286	24.49 ± 3.67[b]	17	34	0.006	185	26.42 ± 4.07[b]	17	37	< 0.001
		2	167	25.20 ± 3.83[a,b]	17	38		131	26.23 ± 3.88[b]	17	38	
		3	150	25.23 ± 3.76[a,b]	17	36		111	28.00 ± 4.49[a]	18	37	
		4 ≤	307	25.54 ± 3.55[a]	17	37		203	28.28 ± 3.75[a]	18	37	

[a,b]Values in columns denoted by different superscript lower-case letters differ significantly among groups ($p < 0.05$). Group A, parity categorized into 1, and 2 or more; Group B, parity categorized into 1, 2, and 3 or more; Group C, parity categorized into 1, 2, 3, and 4 or more. GL, gestation length; BW, birth weight; LBH, line-breeding Hanwoo; GH, general Hanwoo; N, number of animals; SD, standard deviation; MIN, minimum; MAX, maximum.

Effect of parity of the dam

Table 3 shows the analysis results based on the parity of the dam. In LBH, the gestation length was significantly shorter for heifers at 282.65 ± 6.07 days compared with that of cows that had given birth once, which was 283.56 ± 5.85 days (Group A, $p = 0.03$). However, there was no significant difference in the GH (Group A, $p = 0.105$). When classified into one to two parities and three or more parities (Group B), both LBH and GH showed significantly longer gestation lengths during the first to third parity. In LBH, cows with three or more parities had a gestation length of 283.89 ± 5.53 days, which was longer than that in cows with one to two parities, which had a gestation length of 282.66 ± 6.27 days ($p = 0.002$). In GH, cows with three or more parities exhibited a gestation length of 286.13 ± 6.14 days, which was longer than that of cows with fewer than three parities, which had a gestation length of 285.12 ± 6.25 days ($p = 0.041$). In GH, a significant increase in gestation length was noted in the fourth parity with a length of 286.70 ± 6.42 days (Group C, $p = 0.027$).

Both LBH and GH groups showed differences in birth weight according to dam parity. In LBH, the birth weight was significantly heavier for calves from cows (25.37 ± 3.68 kg) than those from heifers (24.49 ± 3.67 kg) (Group A, $p < 0.001$). Similarly, in GH, calves from cows weighed more (27.61 ± 4.07 kg) than those from heifers (26.42 ± 4.07 kg) (Group A, $p < 0.001$). In both the LBH and GH, calves from cows with three or more parities had significantly higher birth weights. In Group B, calves born to LBH cows with one to two parities weighed 24.75 ± 3.74 kg, whereas those born to cows with three or more parities weighed 25.44 ± 3.62 kg (Group B, $p = 0.005$). Similarly, in GH, calves from cows with one to two parities weighed 26.34 ± 3.99 kg, and those from cows with three or more parities showed a significant increase, weighing 28.18 ± 4.02 kg (Group B, $p < 0.001$). In GH, when comparing cows with one to three parities to those with four or more parities, the birth weight of calves produced by cows with four or more parities was significantly higher, weighing 28.28 ± 3.75 kg (Group C, $p < 0.001$).

Effect of calving year

There were significant yearly differences in gestation length for LBH ($p < 0.001$) but not for GH ($p = 0.156$). Significant differences in birth weight were noted according to the year of calving in both the LBH and GH groups ($p < 0.001$). However, both LBH and GH present difficulties in data interpretation as the number of dams used in the analysis varies by year (Table 4).

Effect of calving season

Both LBH and GH exhibited differences in gestation length and birth weight depending on the calving season (Table 5). Among LBH cows, those calving in the fall had a gestation length of 284.76 ± 6.68 days, which was significantly longer than those calving in other seasons (Group A, $p < 0.001$). In the case of GH, the number of cows per four seasons is not uniform, making it difficult to interpret differences between groups. HRI aims for spring and fall calves; thus, AI is predominantly practiced during these seasons. Consequently, we examined the differences in gestation length by focusing on cows calving in the spring and fall (Group B). The average gestation length for LBH cows calving in spring was 282.51 ± 6.17 days, while for fall calvings, it was 284.76 ± 6.68 days, showing a significant difference of over two days (Group B, $p < 0.001$). Similarly, for GH cows, the gestation length for spring calvings was 285.19 ± 6.08 days, which was approximately two days significantly shorter than the gestation length for fall calvings, 287.39 ± 6.26 days (Group B, $p < 0.001$).

The average birth weight of LBH calves born in spring was 25.14 ± 3.56 kg, while those born in fall had an average birth weight of 25.73 ± 3.69 kg. For GH calves, the average birth weight of those born in spring was 27.43 ± 3.86 kg, and for those born in fall, it was 27.33 ± 4.43 kg. However, there was no significant difference in calf birth weight between the calving seasons for either LBH or GH (Group B, $p > 0.05$).

Table 4. Effect of calving year on gestation length and birth weight of calves in two Hanwoo populations

Variation		LBH					GH				
		N	Mean ± SD	MIN	MAX	p	N	Mean ± SD	MIN	MAX	p
GL (day)	2015	4	278.75 ± 5.19^{c}	275	286	< 0.001	–	–	–	–	0.156
	2016	62	281.39 ± 6.04^{b,c}	268	296		42	286.14 ± 8.14	267	308	
	2017	78	284.65 ± 6.08^{a,b}	270	302		52	285.23 ± 5.59	270	297	
	2018	53	282.04 ± 6.43^{a,b,c}	264	297		51	284.73 ± 6.81	268	297	
	2019	123	282.34 ± 7.16^{a,b}	261	301		62	284.24 ± 7.78	264	300	
	2020	157	284.50 ± 6.19^{a,b}	266	309		105	286.12 ± 6.14	268	306	
	2021	105	285.09 ± 4.86^{a}	273	298		104	286.24 ± 6.02	264	307	
	2022	176	283.39 ± 4.64^{a,b}	270	302		103	286.60 ± 5.16	277	310	
	2023	152	282.01 ± 5.64^{a,b,c}	265	297		111	284.86 ± 5.33	273	302	
BW (kg)	2015	4	20.75 ± 2.22^{d}	19	24	< 0.001	–	–	–	–	< 0.001
	2016	62	23.56 ± 3.12^{b,c}	18	34		42	25.38 ± 3.89^{c,d}	18	36	
	2017	78	26.06 ± 2.96^{a}	20	33		52	27.42 ± 3.46^{a,b}	20	37	
	2018	53	22.17 ± 3.30^{c,d}	17	31		51	24.87 ± 4.07^{d}	17	33	
	2019	123	24.52 ± 3.64^{a,b}	17	38		62	26.52 ± 3.87^{b,c}	18	36	
	2020	157	25.89 ± 3.91^{a}	17	36		105	27.62 ± 3.64^{a,b}	20	37	
	2021	105	25.51 ± 3.40^{a,b}	18	37		104	27.17 ± 4.22^{a,b}	17	36	
	2022	176	25.46 ± 3.17^{a,b}	18	34		103	28.49 ± 4.08^{a}	18	38	
	2023	152	25.31 ± 4.19^{a,b}	17	37		111	28.00 ± 4.27^{a,b}	17	37	

$^{a–d}$Values denoted in columns by different superscript lower-case letters differ significantly among groups ($p < 0.001$). GL, gestation length; BW, birth weight; LBH, line-breeding Hanwoo; GH, general Hanwoo; N, number of animals; SD, standard deviation; MIN, minimum; MAX, maximum.

Table 5. Effect of calving season on gestation length and birth weight of calves in two Hanwoo populations

Variation			LBH					GH				
Group		Season	N	Mean ± SD	MIN	MAX	*p*	N	Mean ± SD	MIN	MAX	*p*
GL (day)	A	Spring	295	282.51 ± 6.17^{b}	264	302	< 0.001	314	285.19 ± 6.08^{a,b}	264	307	< 0.001
		Summer	212	283.04 ± 4.81^{b}	263	298		66	281.68 ± 4.50^{c}	271	293	
		Fall	281	284.76 ± 6.68^{a}	261	309		238	287.39 ± 6.26^{a}	264	310	
		Winter	122	282.11 ± 4.52^{b}	265	294		12	283.83 ± 4.15^{b,c}	280	293	
	B	Spring	295	282.51 ± 6.17^{b}	264	302	< 0.001	314	285.19 ± 6.08^{b}	264	307	< 0.001
		Fall	281	284.76 ± 6.68^{a}	261	309		238	287.39 ± 6.26^{a}	264	310	
BW (kg)	A	Spring	295	25.14 ± 3.56	17	38	0.083	314	27.43 ± 3.86	17	38	0.191
		Summer	212	25.15 ± 3.81	17	37		66	26.48 ± 4.05	17	37	
		Fall	281	24.73 ± 3.69	17	36		238	27.33 ± 4.43	17	37	
		Winter	122	25.75 ± 3.76	17	37		12	25.67 ± 3.42	21	34	
	B	Spring	295	25.14 ± 3.56	17	38	0.171	314	27.43 ± 3.86	17	38	0.781
		Fall	281	24.73 ± 3.69	17	36		238	27.33 ± 4.43	17	37	

$^{a-c}$Values denoted in columns by different superscript lower-case letters differ significantly among groups (p < 0.001). Group A, season categorized into spring, summer, fall, and winter; Group B, season compared between spring and fall only. GL, gestation length; BW, birth weight; LBH, line-breeding Hanwoo; GH, general Hanwoo; N, number of animals; SD, standard deviation; MIN, minimum; MAX, maximum.

Table 6. Effect of calf sex on gestation length and birth weight of calves in two Hanwoo populations

Variation		LBH					GH				
		N	Mean ± SD	MIN	MAX	*p*	N	Mean ± SD	MIN	MAX	*p*
GL (day)	Female	469	282.91 ± 5.63	264	305	0.054	314	285.52 ± 6.01	264	307	0.673
	Male	441	283.67 ± 6.22	261	309		316	285.73 ± 6.41	264	310	
BW (kg)	Female	469	24.21 ± 3.39^{b}	17	36	< 0.001	314	26.21 ± 3.90^{b}	17	37	< 0.001
	Male	441	26.04 ± 3.77^{a}	17	38		316	28.30 ± 4.04^{a}	18	38	

^{a,b}Values denoted in columns by different superscript lower-case letters differ significantly among groups (p < 0.001). GL, gestation length; BW, birth weight; LBH, line-breeding Hanwoo; GH, general Hanwoo; N, number of animals; SD, standard deviation; MIN, minimum; MAX, maximum.

Effect of calf sex

The analysis results based on calf sex are described in Table 6. There was no difference in gestation length based on calf sex for either LBH or GH. For LBH, the gestation length of dams producing female calves was 282.91 ± 5.63 days, while for dams producing male calves, it was 283.67 ± 6.22 days (p = 0.054). In GH, the gestation length of dams producing female calves was 285.53 ± 6.01 days, and for dams producing male calves, it was 285.73 ± 6.41 days (p = 0.673). Although the gestation length of dams producing male calves was slightly greater in both populations, the difference was not statistically significant (p > 0.05).

For both LBH and GH, there was a difference in calf birth weight based on sex. In LBH, the average birth weight of female calves was 24.21 ± 3.39 kg, while that of male calves was 26.04 ± 3.77 kg (p < 0.001). In GH, the average birth weight of female calves was 26.21 ± 3.90 kg, and that of male calves was 28.30 ± 4.04 kg (p < 0.001). In both the LBH and GH groups, male calves were significantly heavier than female calves (p < 0.001).

DISCUSSION

Research findings on gestation length and birth weight in cattle breeds are highly diverse. Even within Hanwoo cattle, there have been various reports on a range of significant environmental factors.

Differences in average abilities between the two populations

Shin and Baik (1984) reported an average gestation length of 283.9 days for 192 Hanwoo cows surveyed in Jeonbuk Province from 1981 to 1983. Kwon et al. (2019) reported an average gestation length of 287.602 ± 4.797 days for 58,800 cows in Jeonbuk Province from 2010 to 2017. Eum et al. (2016) reported an average gestation length of 289.69 ± 7.883 days for 10,471 Hanwoo cows raised in Gyeongnam province from 2007 to 2015. Recently, Lopez et al. (2020) reported a gestation length range of 271 to 299 days, with a mean of 286.15 days, for 51,303 Hanwoo cow calves from February 1998 to March 2017. The average gestation length of Hanwoo cows has been reported to range from 283 to 289 days, showing variability depending on the region and the subjects investigated.

The average birth weight of Hanwoo cattle has also been variably reported across different regions and subjects since Shin et al. (1975) documented the average birth weight of 233 Hanwoo cattle in the Daegwallyeong region from 1968 to 1974 as 22.72 ± 0.49 kg. Since then, the birth weight of Hanwoo cattle has steadily increased through improvement, and recently, Lopez et al. (2020) reported that the birth weights of 52,173 Hanwoo born between 1998 and 2017 ranged from 17.0 to 38.3 kg, with an average of 27.41 kg.

In Hanwoo cattle, gestation length appeared to increase, as did the birth weight of calves. In the present study, the gestation lengths and birth weights of LBH and GH were all within the range previously reported for Hanwoo cattle; however, LBH cattle tended to have a shorter gestation length of 283.28 ± 5.93 days and a lower birth weight of 25.10 ± 3.69 kg, compared to average Hanwoo cattle (Table 2).

Andersen and Plum (1965) described a positive relation between dam weight and calf birth weight in both cattle and buffaloes, and a positive correlation between gestation length and calf birth weight. In the present study, the gestation length of LBH cows was significantly shorter than that of GH cows ($p < 0.001$), and their calf birth weights were also significantly lower ($p < 0.001$). LBH is a line-bred population formed using sires selected internally by the HRI, and the pace of improvement is slower than that of populations constituted by the Hanwoo proven bulls. Therefore, LBH cows have lower mature body weights than those of GH cows, resulting in shorter gestation lengths and lower calf birth weights. However, the exact mechanisms underlying smaller mature body weight, shorter gestation length, and smaller birth weight are not yet understood. Further investigation is needed to determine whether there are any distinctive characteristics of LBH cows compared to GH cows regarding the period from conception to parturition.

Effect of dam parity

Shin et al. (1986) reported that in Hanwoo cattle, as parity increases, there is a slight tendency for gestation length to increase, and calves from heifers are the lightest, with calf weight gradually increasing with increasing parity. Kim (2021) found that gestation length is the shortest and birth weight is the lightest for heifers, with both gestation length and birth weight increasing as parity increases up to the seventh parity. In their study of gestation length and birth weight in Hanwoo and Yanbian Yellow cattle, Shin et al. (1999) found that Hanwoo cattle had significantly longer gestation lengths beyond the fifth parity, and birth weight increased from parity one to three. However, there were no significant differences in gestation length or birth weight in Yanbian Yellow cattle.

The results showed that LBH heifers had a significantly shorter gestation length than cows ($p = 0.03$), whereas there was no significant difference between the two groups in GH ($p = 0.105$). However, both LBH and GH cows had significantly shorter gestation lengths in the first and second parities compared with those of cows in parity three or higher ($p < 0.05$), with GH cows showing significantly longer gestation lengths starting from parity four ($p = 0.027$) (Table 3).

For both LBH and GH, the birth weight of calves produced by heifers was significantly lower ($p < 0.001$), and the birth weight of calves produced by cows of third parity or higher was significantly greater than that of calves produced in first or second parity ($p < 0.01$) (Table 3).

Dam parity is generally considered to influence gestation length and birth weight in cattle, with numerous studies reporting that older cows have longer gestation lengths and larger birth weights than heifers. A positive correlation has also been reported between mature dam body weight, gestation length, and calf birth weight (Andersen and Plum, 1965). Therefore, cows with more than two parities tend to have longer gestation lengths and larger calf birth weights than those with insufficient growth in their first two parities.

Effect of calving year

The effect of year on gestation length and calf birth weight in Hanwoo cattle was reported by Shin et al. (1986), who found that gestation length increased slightly and birth weight increased as the years progressed from 1974 to 1984. Numerous studies on Hanwoo birth weight during the 1970s and the 1980s reported a significant increase in birth weight over time, indicating active research and improvement efforts in Hanwoo cattle improvement program. Additionally, significant effects of calving year on birth weight have been reported in several studies (Baik et al., 1985; Choi et al., 1988; Son et al., 1997). Recent research by Kim (2021) also reported a trend of increasing gestation length and a significant increase in birth weight as the calving years progressed. Shin et al. (1999) confirmed significant differences in birth weight by calving year in both Hanwoo and Yanbian Yellow cattle but found no difference in gestation length.

In this study, LBH showed significant differences in both gestation length and birth weight according to calving year, whereas GH only exhibited a difference in birth weight ($p < 0.001$) (Table 4). The variation observed across the calving years encompassed significant differences in various environmental factors. In other words, from insemination to parturition, various environmental factors, such as feed quality, climate change, and management method changes, as well as the effect of sires, can affect gestation length and birth weight. Therefore, stricter environmental management is crucial, and more detailed investigations are needed in the future.

Effect of calving season

The effect of calving season on Hanwoo cattle was also investigated. Shin and Baik (1984) reported that the gestation length of cows calving in spring and summer was approximately two days longer than that of cows calving in fall and winter. However, other studies have reported no significant seasonal differences in gestation length in Hanwoo cattle (Han et al., 1989; Han, 2002). Baik et al. (1985) and Shin et al. (1986) reported that calves born in spring or summer tend to have higher birth weights than those born in fall or winter. However, numerous studies have shown either no effect of season or heavier birth weights in calves born in winter (Shin et al., 1975; Shin and Baik, 1984; Choi et al., 1988; Son et al., 1997).

Kim (2021) reported that gestation length was significantly shorter for cows calving in summer, and the birth weights of calves born in summer and fall were significantly lower than those born in spring and winter. Cho et al. (2021) and Park et al. (2022) found that calves born in summer, including July, had significantly lower birth weights, suggesting that heat stress during the late stages of pregnancy may lead to decreased birth weight and impaired fetal growth.

Both LBH and GH, cows that calved in fall had the longest gestation length ($p < 0.001$). Moreover, calves born in spring from both LBH and GH groups had higher birth weights than those born in fall, although the difference was not statistically significant ($p > 0.05$) (Table 5).

The Daegwallyeong area, where the HRI is located, maintains cool weather even in the summer due to its high altitude compared to other regions in South Korea. In South Korea, the average monthly temperature during the hottest month, August, ranges from 19.7 to 26.7℃. The average maximum temperature in Daegwallyeong during August is 23.6℃ (KMA, 2024). Therefore, it seems that there was no decrease in calf birth weight due to heat stress during summer. However, the environmental differences that dams experience from early to late pregnancy for calving in spring and fall may influence their gestation length. In particular, there was a significant difference in the feed supplied during pregnancy. Cows inseminated in May for calving in March of the following year at the HRI spend their spring consuming hay and rice straw during early pregnancy and receive corn silage during late pregnancy while enduring winter. Conversely, cows inseminated in November received corn silage during early pregnancy and some cows graze on fresh grass during mid-pregnancy. Later in pregnancy, they receive rice straw or hay and experience summer. Corn silage has a high nutrient retention rate and palatability. The nutritional management of dams during pregnancy is reported to regulate fetal development and influence the health and performance of offspring after birth (Šlyžienė et al., 2023). Therefore, seasonal environmental differences appear to have a significant effect on the maintenance of pregnancy and calving.

Effect of calf sex

Shin et al. (1986) and Kim (2021) reported that male calves have significantly longer gestation lengths and higher birth weights than those of female calves. Cho et al. (2021) and Park et al. (2022) also found that the average birth weight of male calves was higher than that of female calves; however, there is also a study showing no significant differences based on sex (Shin and Baik, 1984).

In this study, in both the LBH and GH, the gestation length of cows giving birth to male calves was longer, although the difference was not significant ($p > 0.05$). However, in both populations, male calves had significantly higher birth weights than those of female calves ($p < 0.001$).

It is generally reported that male calves tend to be heavier at birth compared to female calves (Andersen and Plum, 1965). This difference may be attributed to the greater muscle mass and larger skeletal structure in males compared with those in females, which can influence birth weight. However, the exact mechanism by which sex affects birth weight is still not fully understood (Šlyžienė et al., 2023).

CONCLUSION

In the Hanwoo cattle industry, reproductive traits are economically crucial but are often susceptible to environmental influences due to low genetic heritability. Consequently, the impact of environmental factors on gestation length and birth weight has been widely reported to vary depending on the time and subject of the investigation. Additionally, research on reproductive traits has been limited because selection and improvement have primarily focused on carcass traits in Hanwoo cattle (Lopez et al., 2019).

Recently, Lopez et al. (2019) estimated the genetic parameters for four reproductive traits in Hanwoo cattle using a multi-trait model: age at first calving, calving interval, days open, and gestation length. The heritabilities were found to be low, with age at first calving at 0.01, calving interval at 0.03, days open at 0.03, and gestation length at 0.13. The genetic correlations among these traits ranged from low to high levels, with notable correlations between gestation length and other traits; however, they opined that selection may be challenging considering the low heritabilities. Subsequently, Lopez et al. (2020) estimated genetic parameters for birth weight and weaning weight, determining their direct heritabilities to be 0.22 and 0.51, respectively. Birth weight had genetic correlations of 0.06 with age at first calving and 0.21 with gestation length. Birth weight is typically the first trait measured in calves and is considered an important economic indicator because of its positive association with post-weaning daily weight gain and mature weight.

In this study, significant differences were observed between the two populations with different genetic compositions despite exposure to the same feeding and gestational environments. Further investigation is needed to explore these differences. Most importantly, it is essential to understand and utilize environmental factors to select and improve reproductive traits. Moreover, systematic record-keeping on farms can aid in understanding the characteristics of their own populations, which will help in planning the season and age (parity) of cows to use for calving.

There are limitations in studying traits because most reproduction is conducted through AI at the HRI. However, HRI produces high-quality data through systematic research and record management. Thus, along with the findings of this study, it is crucial to expand the number of traits under investigation and continue to pursue a correlation between the collected data and genetic parameter estimates. The results of this study are expected to accurately predict the reproductive traits of Hanwoo cows and serve as foundational data for further improvement.

Author Contributions: Conceptualization, S.J.; methodology, S.J., J.I.W.; investigation, S.J., S-S.K.; data curation, S.J.; writing - original draft preparation, S.J.; writing - review and editing, S.J., S-S.K., J.I.W., H.J.K., S.S.J., S.W.K.; supervision, S.J.; project administration, J.I.W., H.J.K., S.J.; funding acquisition, J.I.W., H.J.K., S.J.

Funding: This research was funded by the Rural Development Administration Research Project (Project Name: Establishment of Line Population for Future Demand, Study of the Genetic Characteristics, and Development of Application Technology for Hanwoo, Project Number: PJ01502802).

Ethical Approval: All experimental procedures were conducted according to national and institutional guidelines and approved by the Ethical Committee of the National Institute of Animal Science, Republic of Korea (approval number: 2020-449).

Consent to Participate: Not applicable.

Consent to Publish: Not applicable.

Availability of Data and Materials: Not applicable.

Acknowledgements: Thank you to all members of the Hanwoo Research Institute for their efforts. A special thanks to Mrs. Sooja Hwang and Mrs. Geumsun Jeon for their assistance.

Conflicts of Interest: No potential conflict of interest relevant to this article was reported.

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