Journal of Animal & Plant Sciences, 35(2): 2025, Page: 602-611
ISSN (print): 1018-7081; ISSN (online): 2309-8694
https://doi.org/10.36899/JAPS.2025.2.0051

EVALUATION OF MORPHOLOGICAL AND GROWTH CHARACTERISTICS AMONG THREE KOREAN NATIVE BLACK GOAT STRAINS

Eun-Do Lee, B. M. Tomple, G. E. Kim, Dong-Kyo Kim, B. H. Choi and Kwan-Woo Kim*

Animal Genetic Resources Research Center, National Institute of Animal Science, Rural Development Administration, Republic of Korea
*Corresponding author's email: bgring@korea.kr

ABSTRACT

The study aimed to investigate and compare the morphological and growth characteristics of three Korean native black goat strains: Dangjin, Jangsu, and Tongyeong. The objective was to test the hypothesis that each strain exhibits unique physical and growth traits, reflecting their genetic and environmental adaptations. These insights are intended to support conservation strategies by providing baseline data essential for the preservation and selective breeding of these genetic resources. A total of 804 goats were assessed from 2010 to 2022, with data collected on coat color, presence of wattles, horn structure, body weight, and measurements (body length, depth, chest width, and chest girth) at various growth stages (birth, 3, 6, 9, and 12 months of age). Body weights and measurements were recorded using a calibrated digital scale and tape measure, respectively, with each goat measured individually by trained personnel to minimize error. Morphological characteristics were noted based on visual inspection. For statistical analysis, a one-way analysis of variance (ANOVA) was conducted using the General Linear Model (GLM) procedure to assess the fixed effects of strain, sex, and age on various growth characteristic variables; and results were presented as means ± standard deviation (SD). The data revealed that they possessed horns and displayed black or dark brown coat colors, but rarely exhibited wattles. Birth weights were generally consistent across strains, though the Tongyeong strain had the lowest birth weights. At 12 months, males and females in the Tongyeong strain significantly exhibited lower body weights and smaller body measurements compared to the Dangjin and Jangsu strains, highlighting a notable distinction in growth patterns among the strains ($p<0.05$). Across all strains, male goats were generally larger than females, with body length and depth measurements showing similar trends ($p<0.05$). Overall, the findings suggest that the Tongyeong strain is characterized by a smaller body size at comparable growth stages, potentially reflecting unique genetic or environmental adaptations within this strain.

Keywords: Genetic resources, Growth characteristics, Korean native black goat, Morphology.

Published first online April 03, 2025 Published final April 28, 2025

INTRODUCTION

Genetic resources are critical to food security, nutrition, and agricultural sustainability, contributing to the resilience and adaptability of global livestock production systems (Pilling *et al*., 2020). In the context of goats, these genetic resources enable selective breeding, improving productivity and adaptability across diverse environments (Pardo *et al*., 2022). Goat breeds exhibit considerable phenotypic diversity due to adaptation to various environments and breeding systems, resulting in differences in coat color, body size, and production traits (Bertolini *et al*., 2018; Wang *et al*., 2016; Gao *et al*., 2020). Growth traits such as body weight and average daily gain are influenced by both genetic and environmental factors, and heritability estimates indicate a potential for selective breeding to enhance these traits (Zhang *et al*., 2009; Wang *et al*., 2023). Additionally, specific genomic regions affect morphological traits like body length and chest diameter, reflecting the influence of long-term selection for different production systems and environmental conditions (Rahmatalla *et al*., 2018). These genetic insights are essential for developing strategies to preserve unique genetic resources in native breeds.

Given the importance of preserving genetic diversity within native goat populations, Korean native black goats represent a unique and valuable genetic resource. Approximately 500 goat breeds have been reported worldwide, 90% of which are local to their regions (FAO, 2007). This global diversity highlights the uniqueness of regional breeds, such as the Korean native black goats. The Korean native black goats are the only Korean goats registered on the Domestic Animal Diversity Information System (DAD-IS, http://dad.fao.org/) of the Food and Agriculture

Organization of the United Nations. Many studies have focused on the Korean native black goats via genetic parameter estimation (Kim *et al*., 2013), growth curve estimation (Lee *et al*., 2016), morphological characteristic and growth performance investigation (Lee *et al*., 2019), and genetic analysis (Kim *et al*., 2012; Suh *et al*., 2012). However, these studies are insufficient compared to those conducted on the goats of other countries.

Goat meat consumption has gradually increased, attracting attention as a functional food due to changing food preferences and the growing social demand for alternatives to dog meat. In Korea, goats are not only increasing in number but are also becoming more specialized. However, the introduction of imported goats has endangered the pure Korean native black goats due to increased crossbreeding aimed at enhancing meat quantity (Lee *et al*., 2019). To preserve and manage the genetic resources of Korean native black goats, it is essential to further explore their morphological and growth characteristics. The initial phase in characterizing local genetic resources involves understanding the variation in morphological traits (Azor *et al*., 2008; Legaz *et al*., 2011).

Despite some studies on Korean native black goats, there is a lack of comprehensive data specifically detailing the morphological and growth characteristics of the distinct strains. These strains have unique traits and phenotypic diversity that are under documented, particularly in comparison to more widely studied native goat breeds in other countries. Understanding these specific characteristics is essential for accurate breed conservation and for developing tailored breeding programs aimed at preserving genetic diversity and preventing crossbreeding dilution. In this context, the analysis of morphological traits has been successfully used to estimate the existence of genetic variations within and between indigenous animal populations (Arandas *et al*., 2017). Therefore, this study systematically investigates and compares the morphological and growth characteristics of these three Korean native black goat strains to fill this gap, providing foundational data necessary for their preservation and sustainable development.

MATERIALS AND METHODS

Study Population: This study focused on three Korean native black goat strains: Dangjin, Jangsu, and Tongyeong in South Korea to provide a comprehensive understanding of the morphological and growth characteristics unique to each strain. Photograph of both male and female individuals from the three Korean native black goat strains: Dangjin, Jangsu, and Tongyeong is presented in Fig. 1. The Animal Genetic Resources Research Center of the National Institute of Animal Science, Rural Development Administration in Korea, collected Korean native black goats from 1997 to 1998 from three distinct regions: Anmyeondo Island (Dangjin), Beonam-myeon town (Jangsu), and Yokjido Island (Tongyeong). These goats were maintained as pure bloodlines to preserve their genetic integrity. A total of 804 goats were included in the study over a substantial period from 2010 to 2022. The specific numbers of goats studied were as follows: 237 Dangjin goats, comprising 119 females and 118 males; 277 Jangsu goats, comprising 140 females and 137 males; and 290 Tongyeong goats, comprising 134 females and 156 males (Table 1).

Data Collection: The study included a representative sample of 804 goats from the Dangjin, Jangsu, and Tongyeong strains, selected to ensure coverage across different age groups, sexes, and family lines within each strain. Sampling was conducted over a 12-year period from 2010 to 2022, with goats chosen from a variety of farms and regions in South Korea to capture the full range of morphological diversity within each strain. Selection criteria ensured an even distribution across sexes, and animals were grouped by birth year to account for potential environmental effects on morphology. To assess morphological characteristics, several key traits were recorded. Coat color was documented for each goat and categorized as black, black-brown, or mixed, with proportions calculated separately for males and females in each strain. The presence or absence of wattles and horns was also documented, as these features are important for distinguishing between strains. Goats without horns were further examined to investigate potential genetic causes, using established genetic markers based on prior research findings.

Growth characteristics, including body weights and measurements of body length, body depth, chest width, and chest girth, were recorded at birth, 3 months, 9 months, and 12 months of age. The daily growth rate was obtained by dividing the weight gain by the number of days within the interval, for an interval spanning 3 months, approximately 90 days were used. Birth weights were measured immediately after birth using a calibrated digital scale with a precision of ±0.1 kg. Subsequent weights were also recorded at the specified intervals using the same scale to ensure consistency across measurements.

To maintain accuracy in body measurements, a flexible measuring tape was used, and all measurements were taken by trained personnel following standardized protocols. Body length was measured from the point of the shoulder to the pin bone, with goats standing on a flat surface to avoid measurement discrepancies. Body depth was measured from the top of the spine to the bottom of the chest at the level of the withers, while chest width was measured between the forelimbs to capture the

broadest part of the chest. Chest girth was measured around the chest, just behind the forelimbs, ensuring that the tape was snug but not compressing the body. To enhance consistency, all measurements were taken by the same team throughout the study and at the same time of day, minimizing variations related to handling or measurement procedures. A photograph illustrating all body measurements recorded in the study, including body length, body depth, chest width, and chest girth, is presented in Fig. 2.

Fig. 1. Photograph of both male and female individuals from the three Korean native black goat strains: Dangjin, Jangsu, and Tongyeong.

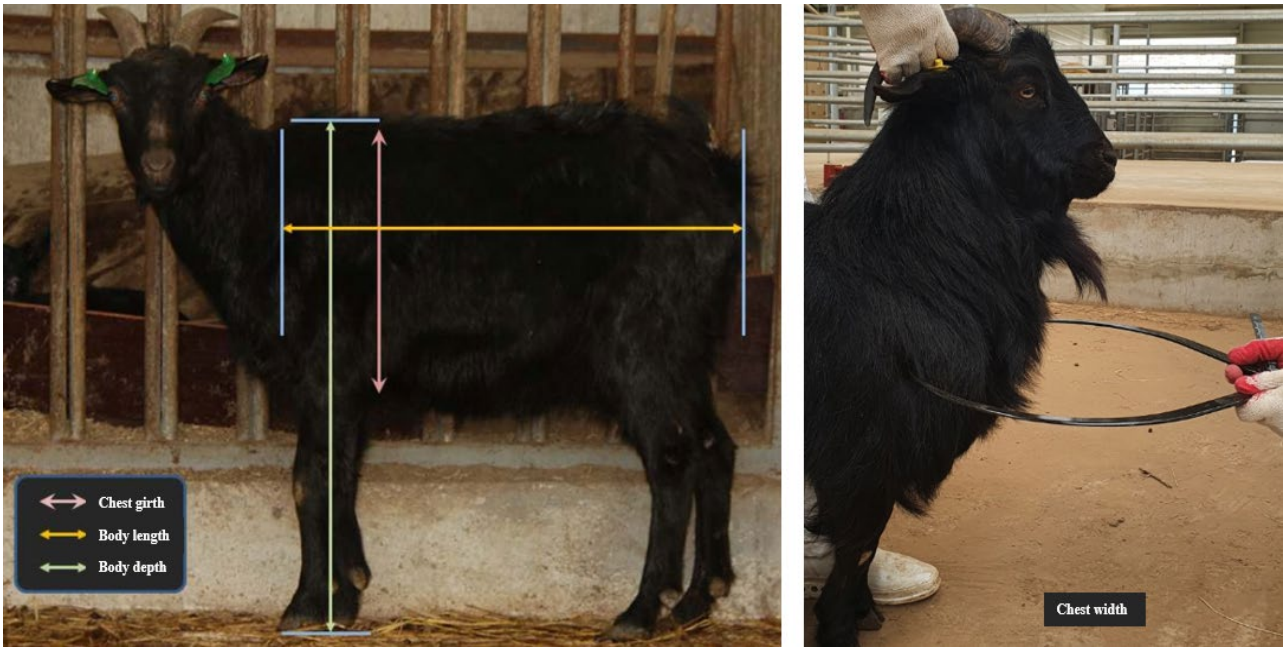

Fig. 2. Photograph illustrating all body measurements taken in the study, including body length, depth, chest width, and girth.

Statistical Analysis: Statistical analyses were conducted using SAS software (version 9.1, SAS Institute, Cary, NY, USA) to evaluate the growth characteristics of three Korean native black goat strains: Dangjin, Jangsu, and Tongyeong. The analysis focused on body weight and various body measurements, including body length, body depth, chest width, and chest girth, across two sexes (female and male) at five different ages (birth, 3, 6, 9, and 12 months of age). A one-way analysis of variance (ANOVA) was performed using the General Linear Model (GLM) procedure. The fixed factors in the model included strain, sex, and age. No interactions were considered between sex and other variables. The GLM procedure allowed for the evaluation of the main effects of strain, sex, and age on the response variables. When significant differences were detected ($p<0.05$), Duncan's Multiple Range Test was applied for post-hoc pairwise comparisons to identify specific differences between the strains. Descriptive statistics, including standard errors was calculated for each variable using the PROC MEANS procedure and all statistical tests were conducted at a 5% significance level ($p<0.05$).

Ethical Considerations: The research was conducted by the National Institute of Animal Science of the Rural Development Administration, adhering to the ethical standards set by the Institutional Animal Care and Use Committee (IACUC) with approval number 2023-597.

RESULTS

Morphological Characteristics and Genetic Insights of Goat Strains: Table 1 presents the morphological characteristics and genetic insights of 804 goats, including coat color and the presence or absence of wattles and horns, from the three Korean native black goat strains (Dangjin, Jangsu, and Tongyeong) investigated between 2010 and 2022. Coat color varied significantly among strains. The Jangsu and Tongyeong strains predominantly displayed an entirely black coat, while Dangjin goats frequently showed a black-brown or mixed coat pattern. Specifically, within the Dangjin strain, black-brown coat color was observed in 93.3% of females, 95.7% of males, and 94.5% overall, contrasting with lower proportions in the Jangsu (2.9% of females, 5.8% of males, 4.4% overall) and Tongyeong strains (0.7% of females, 0.6% of males, 0.7% overall). Mixed coat colors were also most prevalent in the Dangjin strain, appearing in 6.7% of females, 4.3% of males, and 5.5% overall. In comparison, the Jangsu strain exhibited mixed coats in 4.3% of females and 0.7% of males (2.5% overall), and the Tongyeong strain showed 3.7% in females and 1.3% in males (2.4% overall). Wattles were uncommon, present in only 7.5% of all goats. Notably, wattles were absent in Tongyeong goats, while appearing in 1 male (0.7%) in the Jangsu strain and 6.8% of Dangjin goats (evenly distributed between males and females). Horns were present in nearly all goats across strains, with the exception of two Dangjin individuals (one male and one female) who lacked horns, possibly due to genetic factors.

Growth Characteristics of the Korean native black goats

Body weight: Table 2 presented the body weights of the 804 goats from the three Korean native black goat strains (Dangjin, Jangsu, and Tongyeong) investigated between 2010 and 2022. Birth weights ranged from 1.8 to 2.0 kg in females and from 2.0 to 2.2 kg in males, with no significant differences among strains ($p>0.05$), although the Tongyeong strain showed the lowest birth weight overall. At 3 months, Jangsu female goats and Dangjin male goats had the highest average weights, while both female and male goats of the Tongyeong strain exhibited significantly lower weights compared to other strains. By 9 months, average male body weights were 20.8, 20.1, and 18.6 kg for the Dangjin, Jangsu, and Tongyeong strains, respectively, while female body weights were 15.7 , 16.4, and 13.2 kg, with Tongyeong goats consistently weighing less. By 12 months, male body weights ranged from 22.8 to 26.8 kg and female weights from 16.6 to 20.4 kg, with the Tongyeong strain again showing significantly lower weights than Dangjin and Jangsu strains ($p<0.05$).

Table 1. Morphological characteristics of the Korean native black goats.

Items (%)	Dangjin		Jangsu		Tongyeong	
	Female (n=119)	Male (n=118)	Female (n=140)	Male (n=137)	Female (n=134)	Male (n=156)
Coat color						
- All Black	-	-	130	128	128	153
- Black with dark brown	111	113	4	8	1	1
- Black with white patch	8	5	6	1	5	2
Wattles	4	4	-	1	-	-
Hornless	1	1	-	-	-	-

Table 2. Body weight (kg) of Korean native black goats by stage of growth.

Sex	Korean native goats strains	Birth weights F= 413, M= 391 (402±16)	3 month old F= 195, M= 225 (210±21)	6 month old F= 173, M= 199 (186±18)	9 month old F= 167, M= 180 (174±9)	12 month old F= 174, M=188 (181±10)
Female	Dangjin	1.9±0.4	9.0±2.5^{ab}	13.3±3.3^{a}	15.7±3.9^{a}	19.4±4.4^{a}
	Jangsu	2.0±0.3	9.6±2.2^{a}	13.4±2.8^{a}	16.4±3.9^{a}	20.4±4.3^{a}
	Tongyeong	1.8±0.3	8.1±2.0^{b}	10.5±2.4^{b}	13.2±2.7^{c}	16.6±3.3^{b}
	p-value	0.2065	0.0036	0.0206	<0.0001	0.0124
Male	Dangjin	2.2±0.4	11.2±3.1^{a}	14.6±4.2^{ab}	20.8±3.9^{a}	26.8±3.9^{a}
	Jangsu	2.2±0.4	10.7±3.1^{a}	15.2±3.8^{a}	20.1±5.0^{ab}	25.4±6.7^{a}
	Tongyeong	2.0±0.4	9.4±2.8^{b}	13.2±3.8^{b}	18.6±4.2^{b}	22.8±4.7^{b}
	p-value	0.2125	0.0125	0.0030	0.0035	0.0026

$^{a-c}$ Values with different superscripts in columns are significantly different ($p<0.05$); F, number of female goats; M, number of male goats; Values are mean ± SD

Table 3 presented the daily growth rate of three Korean native black goat strains (Dangjin, Jangsu, and Tongyeong) by stage of growth (Birth to 3 month old, 3 to 6 month old, 6 to 9 month old , and 9 to 12 month old).

Body measurement: Tables 4 to 7 present the body measurements (body length, body depth, chest width, and chest girth) for the three Korean native black goat strains: Dangjin, Jangsu, and Tongyeong. Significant differences were observed among most strains for the measured traits ($p<0.05$). At 12 months of age, male goats exhibited body lengths of 66.0 cm for Dangjin, 64.5 cm for Jangsu, and 59.0 cm for Tongyeong ($p<0.05$). For female goats, the respective measurements were 56.1 cm for Dangjin, 56.8 cm for Jangsu, and 54.9 cm for Tongyeong ($p>0.05$). Across both sexes and age groups, the Tongyeong strain consistently demonstrated the shortest body length, highlighting notable structural differences among the strains.

Body depths at 12 months for male goats were measured at 54.0 cm for Dangjin, 52.4 cm for Jangsu, and 46.3 cm for Tongyeong ($p<0.05$), while female goats measured 46.5 cm, 48.3 cm, and 46.0 cm, respectively ($p>0.05$). These results indicated a similar trend in body depth, reflecting modest sexual size dimorphism. No significant differences were observed among the strains for the body depth measurements across two sexes (female and male) at 3 months of age ($p>0.05$).

Chest widths at 12 months for male goats were measured at 23.3 cm for Dangjin, 21.3 cm for Jangsu, and 26.2 cm for Tongyeong ($p<0.05$), while female goats measured 20.3 cm, 23.3 cm, and 22.3 cm, respectively ($p<0.05$). No significant differences were observed among the strains for the Chest widths measurements across two sexes (female and male) at 9 months of age ($p>0.05$).

Chest girth at 12 months for male goats were measured at 66.9 cm for Dangjin, 65.2 cm for Jangsu, and 58.7 cm for Tongyeong ($p<0.05$), while female goats measured 59.5 cm, 58.5 cm, and 56.3 cm, respectively ($p>0.05$). The Dangjin and Jangsu strains displayed comparable chest girth values in males, whereas the Tongyeong strain consistently recorded the lowest measurements. These results highlight structural differences among the strains, with the Tongyeong strain exhibiting a noticeably smaller physique compared to the Dangjin and Jangsu strains. However, no significant differences were observed among the strains for the chest girth measurements across two sexes (female and male) at 3 and 9 months of age ($p>0.05$).

Table 3. Daily growth rate (g) of three Korean native black goat strains by stage of growth.

Sex	Korean native goats strains	Birth to 3 month old F= 304, M= 308 (306±16)	3 to 6 month old F= 184, M= 212 (198±20)	6 to 9 month old F= 186, M= 190 (188±3)	9 to 12 month old F= 171, M= 184 (178± 9)
Female	Dangjin	79±28^{a}	48±26^{a}	27±17^{b}	41±16^{a}
	Jangsu	84±24^{a}	42±20^{a}	33±23^{a}	44±24^{a}
	Tongyeong	70±22^{b}	27±34^{b}	30±14^{a}	38±17^{b}
	p-value	0.0215	<0.0001	0.0015	0.0123
Male	Dangjin	100±34^{a}	38±18^{b}	69±23^{a}	67±21^{a}
	Jangsu	94±34^{a}	50±34^{a}	54±27^{b}	59±29^{a}
	Tongyeong	82±31^{b}	42±12^{b}	60±33^{a}	47±17^{b}
	p-value	<0.0001	<0.0001	0.0025	<0.0001

$^{a-b}$ Values with different superscripts in columns are significantly different ($p<0.05$); F, number of female goats; M, number of male goats; Values are mean ± SD

Table 4. Body length (cm) of Korean native black goats by stage of growth.

Sex	Korean native goats strains	3 month old F= 152, M= 148(150±3)	6 month old F= 135, M= 165 (150±21)	9 month old F= 114, M= 121 (118±5)	12 month old F= 141, M= 146 (144±4)
Female	Dangjin	46.5±1.6[b]	55.3±2.0[ab]	52.3±1.7	56.1±1.9
	Jangsu	50.0±1.6[a]	56.8±2.1[a]	52.9±1.8	56.8±2.0
	Tongyeong	45.3±1.5[b]	52.9±1.8[b]	50.7±1.6	54.9±1.8
	p-value	<.0001	<.0001	0.1254	0.2784
Male	Dangjin	53.8±1.3 [a]	59.6±1.6 [a]	60.4±1.2 [a]	66.0±1.2[a]
	Jangsu	52.0±0.8 [ab]	56.8±1.5[b]	59.9±1.2[a]	64.5±1.6 [a]
	Tongyeong	49.4±0.7 [b]	54.8±1.6[c]	56.9±1.4 [b]	59.0±1.6 [b]
	p-value	0.0122	<.0001	<.0001	<.0001

[a-c] Values with different superscripts in columns are significantly different (p<0.05); F, number of female goats; M, number of male goats; Values are mean ± SD

Table 5. Body depth (cm) of Korean native black goats by stage of growth.

Sex	Korean native goats strains	3 month old F= 154, M= 165 (160±8)	6 month old F= 137, M= 142 (140±4)	9 month old F= 118, M= 121 (120±2)	12 month old F= 147, M= 141 (144±4)
Female	Dangjin	39.2±0.7	42.7±0.6[a]	45.0±1.1[a]	46.5±0.8
	Jangsu	39.5±0.6	42.9±0.6[a]	45.2±0.8[a]	48.3±0.7
	Tongyeong	38.5±0.7	40.9±0.5[b]	42.4±0.7[b]	46.0±0.9
	p-value	0.5400	0.0409	0.0079	0.1417
Male	Dangjin	42.6±0.7	46.3±0.8[a]	51.2±0.9[a]	54.0±0.8[a]
	Jangsu	41.3±0.7	48.1±1.0[a]	49.4±0.9[a]	52.4±0.9[a]
	Tongyeong	41.7±0.6	43.0±0.7[b]	45.3±1.0[b]	46.3±0.9[b]
	p-value	0.4306	0.0007	<.0001	<.0001

[a-c] Values with different superscripts in columns are significantly different (p<0.05); F, number of female goats; M, number of male goats; Values are mean ± SD.

Table 6. Chest width (cm) of Korean native black goats by stage of growth.

Sex	Korean native goats strains	3 month old F= 152, M= 165(159±9)	6 month old F= 135, M= 142(138.5±5)	9 month old F= 114, M= 121 (118±5)	12 month old F= 147, M= 141 (144±4)
Female	Dangjin	16.7±0.9[a]	17.1±1.0[b]	17.9±1.2	20.3±1.3[b]
	Jangsu	14.5±1.0[b]	16.5±1.0[b]	18.3±1.1	23.3±1.1[a]
	Tongyeong	18.5±1.0[a]	20.4±0.6[a]	19.3±1.1	22.3±1.2[a]
	p-value	0.0004	0.0113	0.2630	0.0080
Male	Dangjin	13.6±0.7[b]	17.5±1.0[b]	19.4±1.4	23.3±1.5[ab]
	Jangsu	16.8±1.0[a]	19.3±0.9[a]	19.8±1.7	21.3±1.7[b]
	Tongyeong	17.5±1.0[a]	20.8±0.6[a]	22.4±1.0	26.2±0.8[a]
	p-value	0.0020	0.0081	0.1732	0.0264

[a-b] Values with different superscripts in columns are significantly different (p<0.05); F, number of female goats; M, number of male goats; Values are mean ± SD.

Table 7. Chest girth of Korean native black goats by stage of growth.

Sex	Korean native goats strains	3 month old F= 118, M= 123 (121±4)	6 month old F= 96, M= 110 (103±10)	9 month old F= 90, M= 97 (94±5)	12 month old F= 122, M= 116 (119±4)
Female	Dangjin	50.5±1.3	53.8±0.9	58.9±1.7[a]	59.5±1.6
	Jangsu	49.8±0.8	51.4±1.1	55.7±1.4[ab]	58.5±1.4
	Tongyeong	48.3±0.9	52.3±0.9	54.0±1.2[b]	56.3±1.1
	p-value	0.3405	0.1855	0.0275	0.2842
Male	Dangjin	53.3±1.4	56.3±1.2	63.5±1.6[a]	66.9±2.9[a]
	Jangsu	51.0±0.9	55.2±1.0	58.1±1.2[b]	65.2±1.3[a]
	Tongyeong	50.8±0.9	54.1±1.2	58.5±1.9[b]	58.7±1.5[b]
	p-value	0.1297	0.3609	0.0158	0.0137

[a-b] Values with different superscripts in columns are significantly different (p<0.05); F, number of female goats; M, number of male goats; Values are mean ± SD.

DISCUSSION

Morphological Characteristics and Genetic Insights of Goat Strains: A total of 804 goats from the Dangjin, Jangsu, and Tongyeong strains of Korean native black goats were assessed for coat color, wattles, and horn presence over a 12-year period (Table 1). Except a few, all Jangsu and Tongyeong goats exhibited a black coat color (Fig. 1.). Dangjin goats mainly exhibited a black-brown coat color, but some exhibited different coat colors. The Korean native black goats in this study predominantly exhibited a black coat color, consistent with previous findings by Kim *et al*. (2011) and Lee *et al*. (2019). This black coat color is notably preferred by consumers and farmers in Korea, as it aligns with cultural preferences and market demand. Similarly, Muhammad *et al*. (2015) reported that farmers showed a preference for specific coat colors in Beetal goats due to their association with desirable traits such as maturity, conception rate, and litter size. Given these preferences, efforts to stabilize the black coat color within Korean native black goat populations are essential for supporting breed conservation and meeting industry needs. Interestingly, genetic studies have indicated that coat color is influenced by complex biological pathways. Bhat *et al*. (2019) found that differentially expressed genes in black, brown, and white Pashmina goats were significantly associated with pathways involved in melanin biosynthesis, melanocyte differentiation, pigmentation development, and melanosome transport. Additional studies are required to stabilize the coat color in Korean native black goats. On the other hand, the results of the investigation of wattles in the three different Korean native black goat strains were as follows: 0.7% male in the Jangsu strain and 6.8% in the Dangjin goats (evenly distributed between males and females) exhibited wattles, but no wattles were observed in the Tongyeong goats. The presence of wattles in goats is under genetic control and is often inherited in a dominant manner. Studies have identified multiple genes related to cartilage development that influence the presence of wattles, suggesting a complex genetic basis (Zhang *et al*., 2022; Reber *et al*., 2015). In the case of Korean native black goats, our investigation revealed that all goats, except for 2 Dangjin goats (1 female and 1 male), had horns. The absence of horns in these 2 Dangjin goats is likely due to genetic factors. Research by Pailhoux *et al*. (2001, 2005) indicates that the absence of horns in goats can be attributed to the PISRT1 gene, the forkhead box L2 gene, and an 11.7-kb deletion. Additionally, Simon *et al*. (2020) confirmed that the lack of horns in goats could result from a complex structural variant involving a deletion and an inversely inserted segment on chromosome 1.

Growth Characteristics of the Korean native black goats

Body weight: The body weights of goats from the Dangjin, Jangsu, and Tongyeong strains of Korean native black goats, assessed investigated over a 12-year period, are presented in Table 2. Birth weights showed minor strain differences, with no statistically significant differences among strains ($p>0.05$). Similarly, Afzal *et al*. (2004) reported that birth weights for male and female kids were relatively similar, at 3.5 kg and 3.3 kg, respectively. These values were slightly higher than the birth weights observed in both male and female kids in the present study. However, the Tongyeong strain had the lowest birth weight across all strains, though this difference was not statistically significant. At 3 months of age, weight differences became more pronounced. Female goats in the Jangsu strain and male goats in the Dangjin strain had the highest weights among strains, with both female and male goats of the Tongyeong strain showing significantly lower weights than those of other strains ($p<0.05$). At 9 month of age, body weights of male goats were 20.8, 20.1, and 18.6 kg, whereas those of female goats were 15.7, 16.4, and 13.2 kg in the Dangjin, Jangsu, and Tongyeong strains, respectively, with significant differences among strains ($p<0.05$) particularly for the Tongyeong strain, which consistently exhibited the lowest weights. In the previous studies of Kuthu *et al*., (2013), the means for birth weight, weaning weight, 6-month weight, 9-month weight, and yearling weight were 1.7, 9.6, 11.7, 16.7, and 21.07 kg, respectively. According to the growth curve estimated via the Gompertz model, the maximum growth rate was reached at approximately 234 days (18 kg) in male goats and 235 days (13 kg) in female goats (Lee *et al*., 2016). These values align closely with findings from the Tongyeong strain in this study. By 12 months, male body weights ranged from 22.8 to 26.8 kg and female body weights from 16.6 to 20.4 kg, with the Tongyeong strain significantly lower than the Dangjin and Jangsu strains ($p<0.05$). This finding corroborates the work of Mandal *et al*. (2022), who reported that male goats were 16.8% heavier than females at this age, indicating modest sexual dimorphism in Korean native black goats. Iqbal *et al*., (2014) also reported that male goats were found to be heavier and longer than females and the body measurements varied with the increasing age of goats. In comparison to Boer and Angora goats, which reach approximately 45.1 kg and 34 kg, respectively, by 12 months (Kadel *et al*. 2020; McGregor *et al*., 2008), the Korean native black goats showed relatively lower weights at the same age. The daily growth rate in this study was obtained by dividing the weight gain by the number of days within the interval. For an interval spanning 3 months, approximately 90 days were used in the Table 3 and followed a similar pattern as body

weights of goats from the Dangjin, Jangsu, and Tongyeong strains of Korean native black goats.

Body measurement: The body measurements of Korean native black goats from the Dangjin, Jangsu, and Tongyeong strains are presented in Tables 4 to 7. These measurements provide a detailed view of the physical differences among the Dangjin, Jangsu, and Tongyeong strains, illustrating the variations in their growth patterns and physical characteristics (Fig. 2.). The body lengths at 12 months of age for male goats of Dangjin, Jangsu, and Tongyeong (65.9, 64.5, and 60.4 cm, respectively) were longer than the body length at 12 months of age for female goats (58.3, 58.1, and 55.9 cm, respectively). Baneh *et al*. (2021) reported that male and female goats have different body lengths at 12 months of age due to high and positive genetic correlations between the sexes, indicating selection for body weight in males results in a correlated response in females. Consistent with this, our study found that the Tongyeong strain exhibited the shortest body length among all strains. The body depths at 12 months of age for male goats of Dangjin, Jangsu, and Tongyeong (54.0, 52.4 and 46.3 cm, respectively) were higher than the body length at 12 months of age for female goats (46.5, 48.3, and 46.0 cm, respectively). Body depth exhibited a trend similar to body length, reflecting modest sexual size dimorphism. This finding aligns with Mandal *et al*. (2022), who reported that at 12 months, male goats were heavier than female goats, demonstrating modest sexual size dimorphism in traits such as body depth, length, and height. The chest width of the Korean native black goats varied also by strain, measuring 21.3 cm to 26.2 cm in male goats and 20.3 cm to 22.3 cm in female goats ($p<0.05$) at 12 months. Notably, the Tongyeong strain exhibited a relatively longer chest width than the other strains. Notably, the Tongyeong strain exhibited a relatively longer chest width compared to the other strains. Iqbal *et al*., (2013) reported that the body length, height at withers, and chest girth of Beetal goats were 27.0 cm, 28.3 cm, 27.0 cm, respectively. Chest girth measurements also varied among the strains. At 12 months, male goats exhibited chest girths ranging from 58.7 cm to 66.9 ($p<0.05$), while female goats ranged from 56.3 cm to 59.5 cm ($p>0.05$). The Dangjin and Jangsu strains exhibited similar measurements, whereas the Tongyeong strain had the lowest measurements. The smaller physique of the Tongyeong strain compared to the other strains indicates differences in body structure that may be influenced by body weight. Badaruddin *et al*. (2022) reported that age differences between male and female goats significantly affect body length, shoulder height, chest circumference, hip height, hip width, and body weight. Additionally, Ijaz *et al*. (2024) noted that goat breeds differ significantly in body weight, heart girth, body length, body height, and chest length, supporting the notion that genetic and environmental factors contribute to morphological variations among goat populations.

Conclusions: This study examined the morphological and growth traits of three Korean native black goat strains to support their preservation efforts. Notable differences in coat color and the presence of wattles distinguished the strains: Jangsu and Tongyeong goats primarily had black coats, while Dangjin goats displayed mixed black-brown colors. Wattles were observed in a few Dangjin and Jangsu goats but were absent in Tongyeong goats, highlighting breed-specific features. Body weight analyses showed that Tongyeong goats consistently had the lowest weights from birth to 12 months, as well as shorter body lengths, smaller depths, and narrower chest girths compared to the Dangjin and Jangsu strains. These findings provide essential insights for developing conservation and breeding strategies aimed at preserving the unique genetic resources of these goat strains. Further research on genetic stabilization and growth enhancement is vital for their sustainable improvement.

Acknowledgments: This study was supported by the "Discover superior traits and develop major commercial stock in goat"(Project No. PJ017233) collaborative research program between University and Rural Development Administration, Republic of Korea.

Conflict of interest: The authors declare that there are no conflicts of interest.

Author contributions: Eun-Do Lee, Byamungu Mayange Tomple, Ga Eun Kim, Dong-Kyo, Bong-Hwan Choi and Kwan-Woo Kim conceptualized the study and curated the data; Eun-Do Lee, Byamungu Mayange Tomple, and Kwan-Woo Kim wrote the manuscript, conducted statistical analysis and evaluation of result.

REFERENCES

Afzal, M., K. Javed and M. Shafiq (2004). Environmental effects on birth weight in Beetal kids. Pakistan Vet. J. 24(2): 104-106

Arandas, J.K.G., N.M.V. da Silva, R.B. Nascimento, E.C.P. Filho, L.H.A. Brasil and M.N. Ribeiro (2017). Multivariate analysis as a tool for phenotypic characterization of an endangered breed. J. Appl. Anim. Res. 45, 152–158 DOI: https://doi.org/10.1080/09712119.2015.1125353.

Azor, P.J., F. Goyache and J.P. Gutiérrez (2008). Genetic and statistical methods for population differentiation. In: Andalusian Regional Government (Ed.), Andalusian Livestock Farming in the 21st Century. Andalusian Livestock Heritage, III. , pp. 169–184. (in

Spanish)

Badaruddin, R., A. Indi, H. Hadini, R. Aka and L. Munadi (2022). Morphometric differences in body dimensions of local goats Ladongi district, East Kolaka Regency. J. Learning and Nucleus Biology. 8(2): 225-235 (in Indonesian) DOI: https://doi.org/10.36987/jpbn.v8i2.2560.

Baneh, H., M. Ghaderi-Zefrehei, R. Pouryaei and A. Mandal (2021). Genetic analysis of sexual size dimorphism in Markhoz goat. Trop Anim Health Prod. 53: 67. DOI: https://doi.org/10.1007/s11250-020-02528-8.

Bertolini, F., B. Servin, A. Talenti, E. Rochat, E. Kim, C. Oget, I. Palhière, A. Crisà, G. Catillo, R. Steri, M. Amills, L. Colli, G. Marras, M. Milanesi, E. Nicolazzi, B. Rosen, C. Tassell, B. Guldbrandtsen, T. Sonstegard, G. Tosser-Klopp, A. Stella, M. Rothschild, S. Joost and P. Crepaldi (2018). Signatures of selection and environmental adaptation across the goat genome post-domestication. Genetics, Selection, Evolution : GSE, 50. DOI: https://doi.org/10.1186/s12711-018-0421-y.

Bhat, B., A. Singh, Z. Iqbal, J.K. Kaushik, A.R. Rao, S.M. Ahmad, H.B. Aadil Ayaz, F.D. Sheikh, S. Kalra, S. Shanaz, M.S. Mir, P.K. Agarwal, T. Mohapatra and N.A. Ganai (2019). Comparative transcriptome analysis reveals the genetic basis of coat color variation in Pashmina goat. Sci. Rep. 9: 6361 DOI: https://doi.org/10.1038/s41598-019-42676-y.

Food and Agriculture Organization (FAO) (2007). The State of the World's Animal Genetic Resources for Food and Agriculture (Eds.) FAO. Rome. Richkowsky, B and D. Pilling [last visit July 22, 2024] Available from: https://www.fao.org/4/a1250e/a1250e.pdf

Gao, J., Y. Lyu, D. Zhang, K. Reddi, F. Sun, J. Yi, C. Liu, H. Li, H. Yao, J. Dai and F. Xu (2020). Genomic characteristics and selection signatures in indigenous Chongming white goat (*Capra hircus*). Front. Genet. 11: 901 DOI: https://doi.org/10.3389/fgene.2020.00901.

Ijaz A., M. Moaeen-ud-Din, S. M. Suhail, R. Khan and S. Khan (2024). Evaluation of Sindh goat breeds performances for body measurements, body weight, productive and reproductive traits. J. Anim. Plant Sci. 34(1): 253-259 DOI: https://doi.org/10.36899/JAPS.2024.1.0713

Iqbal, Z. M., K. Javed, M. Abdullah, N. Ahmad, A. Ali, A. Khalique, N. Aslam and U. Younas (2014). Estimation of body weight from different morphometric measurements in Kajli lambs. J. Anim. Plant Sci. 24(3): 700-703

Iqbal, M., K. Javed and N. Ahmad (2013). Prediction of body weight through body measurements in Beetal goats. Pakistan J. Sci. 65(4): 458-461.

Kadel, R., S. Malla, S. Ghimire, B. KC and P. Shrestha (2020). Growth performance of Boer goat in relation to sex and type of birth at the Goat Research Station in Nepal. Bang. J. Anim. Sci. 49(2): 166-169 DOI: https://doi.org/10.3329/bjas.v49i2.53228.

Kim, J., C. Cho, S. Choi, Y. Cho, S. Yeon and S. Yang (2011). mtDNA Diversity and phylogenetic analysis of Korean native goats. J. Life Sci. 21(9): 1329-1335. DOI: https://doi.org/10.5352/JLS.2011.21.9.1329.

Kim, J.H., M.J. Byun, Y.G. Ko, S.W. Kim, S.W. Kim, Y.J. Do, M.J. Kim, S.H. Yoon and S.B. Choi (2012). Phylogenetic analysis of Korean native goats based on the mitochondrial cytochrome B gene. J. Anim. Sci. Technol. 54: 241-246. DOI: https://doi.org/10.5187/JAST.2012.54.4.241.

Kim, M.J., S.W. Kim, J.H. Kim, M.J. Byeon, C.S. So and Y.M. Jo (2013). Estimation of genetic parameters for the litter size and birth weight in Korean black goats. Ann. Anim. Resour. Sci. 24:1-5. DOI: http://dx.doi.org/10.12718/AARS.2015.26.1.1.

Kuthu, Z. H., K. Javed, M.E. Babar, Abdul Sattar and M. Abdullah (2013). Environmental effects on growth traits of teddy goats. J. Anim. Plant Sci. 23(3): 692-698.

Lee, S.H., J.W. Lee, D.Y. Jeon, S.C. Kim and K.W. Kim (2019). Morphological characteristics and growth performance of Korean native black goats. JKAIS. 20:149-155 DOI: https://doi.org/10.5762/KAIS.2019.20.8.149

Lee, S.S., S.W. Kim, K.W. Kim, H.Y. Cho, C.Y. Cho, S.H. Yeon and T.J. Choi (2016). Growth curve parameters for body weight by sex in Korean native goat. Ann. Anim. Resour. Sci. 27: 152-158. DOI: https://doi.org/10.12718/AARS.2016.27.3.158.

Legaz, E., I. Cervantes, M.A. Pérez-Cabal, L.F. de la Fuente, R. Mártinez, F. Goyache and J.P. Gutiérrez (2011). Multivariate characterization of morphological traits in Assaf (Assaf. E) sheep. Small Rumin. Res. 100 (2-3): 122-130 DOI: https://doi.org/10.1016/j.smallrumres.2011.06.005.

Mandal, A., H. Baneh, P. Rout and D. Notter (2022). Genetic analysis of sexual dimorphism in growth of Jamunapari goats of India. J. Anim. Breed Genet. 139: 462–475. DOI: https://doi.org/10.1111/jbg.12670.

Mcgregor, B.A. and K.L. Butler (2008). Butler relationship of body condition score, live weight, stocking rate and grazing system to the mortality of Angora goats from hypothermia

and their use in the assessment of welfare risks. Aust. Vet. J. 86: 12-17. DOI: https://doi.org/10.1111/j.1751-0813.2007.00249.x.

Muhammad M.S., M. Abdullah, M.S. Khan, K. Javed and M.A. Jabbar (2015). Farmer's preferences for goat breeds in Punjab, Pakistan. J. Anim. Plant Sci. 25(2): 380-386

Pailhoux, E., B. Vigier, S. Chaffaux, N. Servel, S. Taourit, J.P. Furet, M. Fellous, F. Grosclaude, E.P. Cribiu, C. Cotinot and D.A. Vaiman (2001). 11.7-kb deletion triggers intersexuality and polledness in goats. Nat. Genet. 29: 453-458. https://www.nature.com/articles/ng769z.

Pailhoux, E., B. Vigier, L. Schibler, E.P. Cribiu, C. Cotinot and D. Vaiman (2005). Positional cloning of the PIS mutation in goats and its impact on understanding mammalian sex-differentiation. Genet. Sel. Evol. 37(1): S55 DOI: https://link.springer.com/article/10.1186/1297-9686-37-S1-S55

Pardo, J., J. Bermejo, A. Ariza, J. Jurado, C. Navas, C. Pastrana, M. Martínez and F. González (2022). Candidate genes and their expressions involved in the regulation of milk and meat production and quality in goats (*Capra hircus*). J Anim. 12(8): 988. DOI: https://doi.org/10.3390/ani12080988.

Pilling, D., J. Bélanger, S. Diulgheroff, J. Koskela, G. Leroy, G. Mair and I. Hoffmann (2020). Global status of genetic resources for food and agriculture: challenges and research needs. Gen. Res. J. 1:4-16. DOI: https://doi.org/10.46265/genresj.2020.1.4-16.

Rahmatalla, S., D. Arends, M. Reissmann, K. Wimmers, H. Reyer and G. Brockmann (2018). Genome-wide association study of body morphological traits in Sudanese goats. Anim. Genet. 49(5): 478-482 DOI: https://doi.org/10.1111/age.12686.

Reber, I., I. Keller, D. Becker, C. Flury, M. Welle and C. Drögemüller (2015). Wattles in goats are associated with the FMN1/GREM1 region on chromosome 10. Anim. Genet. 46(3): 316-320. DOI: https://doi.org/10.1111/age.12279.

SAS Institute Inc. (2016). SAS/STAT® 9.4 User's Guide. Cary, NC, USA: SAS Institute Inc.

Simon, R., H. Lischer, A. Pieńkowska-Schelling, I. Keller, I. Häfliger, A. Letko, C. Schelling, G. Lühken and C. Drögemüller (2020). New genomic features of the polled intersex syndrome variant in goats unraveled by long-read whole-genome sequencing. Anim. Genet. 51(3): 439-448. DOI: https://doi.org/10.1111/age.12918.

Suh, S., M, Byun, Y.S. Kim, M.Y. Kim, S.B. Choi, Y.G. Ko, D.H. Kim, H.T. Lim and J.H. Kim (2012). Analysis of genetic diversity and relationships of Korean native goat populations by microsatellite markers. J. Life Sci. 22:1493-1499. DOI: https://doi.org/10.5352/JLS.2012.22.11.1493.

Wang, R., Y. Liu, Y. Shi, Y. Qi, Y. Li, Z. Wang, Y. Zhang, Y. Zhao, R. Su and J. Li (2023). Study of genetic parameters for pre-weaning growth traits in inner Mongolia white Arbas cashmere goats. Frontiers in Veterinary Science, 9. DOI: https://doi.org/10.3389/fvets.2022.1026528.

Wang, X., J. Liu, G. Zhou, J. Guo, H. Yan, Y. Niu, Y. Li, C. Yuan, R. Geng, X. Lan, X. An, X. Tian, H. Zhou, J. Song, Y. Jiang and Y. Chen (2016). Whole-genome sequencing of eight goat populations for the detection of selection signatures underlying production and adaptive traits. Sci Rep. 6: 38932. https://www.nature.com/articles/srep38932.

Zhang, C., Y. Zhang, D. Xu, X. Li, J. Su and L. Yang (2009). Genetic and phenotypic parameter estimates for growth traits in Boer goat. Livest. Sci. 124(1-3): 66-71. DOI: https://doi.org/10.1016/J.LIVSCI.2008.12.010.

Zhang, W., Y. Yuan, H. Zhang, Y. He, C. Liu, L. Xu, B. Yang, R. Ren and G. Wang (2022). Genetic basis investigation of wattle phenotype in goat using genome-wide sequence data. Anim. Genet. 53(5): 700-705 DOI: https://doi.org/10.1111/age.13235.