REVIEW

J Anim Sci Technol 2023;65(6):1169-1179
https://doi.org/10.5187/jast.2023.e120

JAST
Journal of Animal Science and Technology
pISSN 2672-0191 eISSN 2055-0391

The current status of Korean native pig production

Esther Lee[#], Jae-Cheol Jang[#] and Sang-Hyon OH*

Division of Animal Science, Gyeongsang National University, Jinju 52725, Korea

Received: Oct 23, 2023
Revised: Oct 27, 2023
Accepted: Oct 27, 2023

[#]These authors contributed equally to this work.

***Corresponding author**
Sang-Hyon OH
Division of Animal Science, Gyeongsang National University, Jinju 52725, Korea.
Tel: +82-55-772-3285
E-mail: shoh@gnu.ac.kr

ORCID
Esther Lee
https://orcid.org/0009-0009-3883-5736
Jae-Cheol Jang
https://orcid.org/0000-0001-9843-3186
Sang-Hyon OH
https://orcid.org/0000-0002-9696-9638

Competing interests
No potential conflict of interest relevant to this article was reported.

Funding sources
Not applicable.

Acknowledgements
Not applicable.

Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: OH SH.
Data curation: Lee E, Jang JC, OH SH.

Abstract

Korean native pigs (KNPs) have been one of the traditional livestock primarily raised in rural areas of Korea for centuries. KNPs have adapted to the climate and geography of the Korean Peninsula for a long time, exhibiting excellent adaptability even in challenging environments. For these reasons, the preservation and purification of KNPs are crucial in securing unique genetic resources. Therefore, this review covers the characteristics, production status, commercial value and potential breeding directions of KNPs. Unfortunately, there is still a long way to go for the improvement of KNPs. It is crucial to acknowledge the current challenges, identify the issues, and dedicate efforts to the breed's improvement. Each section of this comprehensive review will play an important role in integrating related research and data into the overall findings. In-depth discussions on the genetic diversity, productivity, genetic conservation, ecological roles, and sustainability of KNPs will be crucial components in the future of KNP business.

Keywords: Korean native pigs, Growth, Genetic parameters, Reproductive performance, Meat quality, Price

INTRODUCTION

In the latter half of the 20th century, the global pork industry witnessed remarkable advancements in pig breeding, leading to larger swine farms, increased ownership concentration, and greater industrialization in farming practices. Consumer preferences have also evolved significantly. Amid recent concerns about food safety related to meat consumption, consumers now exhibit a pattern of considering meat quality rather than simply obtaining meat for protein, even if it may be slightly more expensive [1].

Korean native pigs (KNPs) have been one of the traditional livestock raised in rural areas of Korea for centuries. KNPs have adapted to the climate and geography of the Korean Peninsula, and exhibit excellent adaptability even in challenging environments. These pigs are one of the primary sources of pork, a traditional staple in Korean cuisine, and they have had a profound influence on Korean food culture. This pork possesses flavors and scents that resonate with the preferences and emotions of the Korean people [2].

KNPs typically have a smaller body size, longer time to maturity, and lower productivity rate compared to commercial breeds (CBs) imported from overseas. Even though the reproductive and growth traits may be lower in KNPs compared to CBs, they are highly regarded as breeding materials for producing high-quality pork and specialty products because their meat is redder in

Formal analysis: Lee E, Jang JC, OH SH.
Methodology: OH SH.
Software: OH SH.
Validation: Lee E, Jang JC, OH SH.
Investigation: Lee E, Jang JC, OH SH.
Writing - original draft: Lee E, Jang JC, OH SH.
Writing - review & editing: Lee E, Jang JC, OH SH.

Ethics approval and consent to participate
This article does not require IRB/IACUC approval because there are no human and animal participants.

color, has a higher water-holding capacity, more juiciness, more tenderness, and excellent flavor. [3]. Consequently, shifting consumer perceptions towards KNP pork has driven an upsurge in private sector breeding, positioning KNPs as significant indigenous genetic resources within Korea. However, unplanned crossbreeding during the Japanese colonial period led to the ongoing exacerbation of hybridization, and various crossbred forms have been raised as a result. Therefore, the restoration of purebred KNPs has become an urgent task to preserve their genetic resources and strengthen the foundation for their industrial utilization.

KNP genetic diversity and history have sparked significant interest in the fields of genetics, animal husbandry, and conservation biology. With recent advancements in the field of genetic engineering, the importance of traditional livestock has increased not only in terms of economic value but also in terms of breeding resources to discover genomes that enhance productivity [2]. Furthermore, KNPs are highly valued as they are sometimes used in foreign countries as subjects for human organ replacement research.

Historically, KNPs were used for crossbreeding with CBs to improve their productivity. However, they are now recognized as versatile resources and important assets for securing unique genetic materials. Particularly in the livestock sector, their potential for popular pork production and branded meat products is being considered. For these reasons, the preservation and purification of KNPs are crucial in securing unique genetic resources. Therefore, this review will cover the characteristics, production status, commercial value and potential breeding directions of KNPs.

HISTORICAL BACKGROUND

KNPs are known to be a small-sized breed, and are estimated to be the only domesticated black pig breed in Korea. They have been documented to have settled in the country approximately 2,000 years ago during the Goguryeo period, likely originating from the northern regions of China [2,4]. Over the centuries, they have played a vital role in subsistence farming by producing meat, leather, and fertilizers in harsh environmental conditions, while having minimal to no crossbreeding with external pig breeds. These pigs have sometimes been referred to by regional names such as Jiree pig, Sacheon pig, Ganghwa pig, and so on.

KNPs faced the threat of near extinction due to a combination of historical events, including the 1910 annexation by Japan, policy neglect, and extensive crossbreeding with imported CBs. Crossbreeding occurred due to the introduction of Berkshire and Yorkshire breeds after the Protectorate Treaty between Korea and Japan concluded in 1905 and the Korea-Japan Annexation. The colonial government of Joseon evaluated KNPs as low-grade breeds with small stature and low productivity, so they actively encouraged crossbreeding with foreign breeds to enhance their productivity (e.g., they promoted crossbreeding with Berkshire pigs from 1908). As a result, the purity of KNPs nearly disappeared, and after liberation from Japan, increased breeding and the utilization of introduced breeds aimed at enhancing productivity led to the near-extinction of KNPs. However, in some remote mountainous districts or isolated regions, there has been special interest in maintaining a form of KNP that has been crossbred with Berkshire breeds, and only a very small percentage has preserved the pure form of KNPs.

Due to the various improved CBs introduced to Korea, KNPs faced their highest level of extinction risk in the 1980s. However, the National Institute of Animal Science (NIAS) collected KNPs and established a foundation population of them in 1988 [5]. In the late 1980s, authorities in the Livestock Policy Division of the Ministry of Agriculture and Forestry began showing heightened awareness of genetic resources and significant interest in native pig breeds. They began collecting indigenous pigs known by various names in the private sector, such as tojong or black pig,

https://doi.org/10.5187/jast.2023.e120

which initiated research in this field. In addition, the Livestock Research Institute (currently the NIAS) began conducting research to restore the purity of KNPs in 1998 [2].

In recent times, there has been a growing preference among the public for the excellent meat quality and taste that can only be obtained from unique traditional resources, so active research is being conducted to restore unique meat flavors by genetically identifying, maintaining, and improving KNPs that are suitable for extensive farm raising. Furthermore, KNP producers have been altering their perception of traditional pork as there is an expanding demand for livestock products that match consumers' preferences [6].

In 1992, the United Nations Environment Programme (UNEP) stated the importance of preserving traditional livestock as genetic resources for the future. This raised awareness about biodiversity extinction and conservation on a global scale. Along with this interest, the Convention on Biological Diversity came into effect in 1993, establishing the framework for the economic value of biological and genetic resources and the expanded use of biotechnology. This led countries around the world to increase their research and interest in the conservation and value of traditional breeds that are decreasing in numbers, becoming rare, or facing the threat of extinction, without considering their economic value. Korea has also responded to this global trend by showing a growing interest in the preservation and conservation of native breeds through active research related to the collection of native pigs [2].

CHARACTERISTICS OF KOREAN NATIVE PIGS

KNPs are distinct from other pig breeds because of their small and slender body shape. They are mostly classified as small to medium-sized pigs with relatively light body weights, but rich meat quality. Their short hair comes in various colors, predominantly black, brown, and white. These pigs are commonly raised in outdoor settings, allowing them to roam freely and forage in a natural environment. KNPs display genetic diversity within the Korean region, and genotypes with different characteristics exist depending on the region.

KNPs are characterized by high fat content, a rich red meat color, firm fat tissues, and abundant juiciness, making them delicious and flavorful. However, KNPs have a slower growth rate, a lower feed efficiency, fewer offspring, and a smaller body size compared to CBs, which makes them economically disadvantageous to raise [7–12]. Kim and Choi [4] also reported that KNPs have lower productivity compared to CBs, while Hwang et al. [13] and Kim et al. [14] noted that KNPs exhibit superior meat quality such as meat color and marbling.

In the past, KNPs were commonly raised in rural areas. However, there has been a shift towards using CBs to increase profits and to modernize farms. Nonetheless, the genetic diversity and traditional value of these pigs are still highly regarded and preserved. Many farms and institutions are actively running programs dedicated to the conservation and genetic preservation of KNPs, and there are ongoing efforts to protect the genetic diversity and cultural significance of KNPs.

POPULATION

Accurate statistics on the number of domestically raised KNPs are not available, but according to a survey conducted in 1996 by promotion centers in eight provinces, the number was estimated to be around 9,138 [15]. However, this number mainly consisted of crossbred descendants, and in many farms, both black pigs and crossbred pigs were referred to as KNPs.

Currently, national institutions involved in breeding KNPs include the NIAS, Jeju Provincial Livestock Institute (JPLI), and various provincial livestock research institutes (livestock breeding

farms). Privately, KNPs are distributed nationwide, but they are primarily raised on a significant scale in regions such as Jeongseon, Taebaek, Hongcheon, and Goseong in the Gangwon Province, as well as the Pohang region in the Gyeongsangbuk Province.

From the late 1980s, there has been an increase in interest in native pig breeds and a growing awareness of the importance of genetic resources. This has led to research and collection activities related to native pig breeds. Through these efforts, institutions like the JPLI and the Chungbuk Livestock Breeding Farm started breeding programs for KNPs, and KNPs were successfully registered as a breed in 2008, marking the successful restoration of the pure native pig breed.

In 2021, there were 328 Korean native black pigs being raised and conserved, and a total of 7,808 pigs had been distributed to local farmers between 1987 and 2022, according to the JPLI statistics (Fig. 1). Approximately 100 purebred KNPs have been consistently registered each year since 2008. These registrations are primarily managed by key institutions such as the NIAS, JPLI, Chungbuk Livestock and Veterinary Service, and Sanuri Farm. However, current KNPs have low productivity, so government agencies have taken the lead in maintaining their bloodlines. In such a situation, continuous research is needed to industrially utilize KNPs on farms and to conserve them as genetic resources.

GENETICS

There is limited research estimating the genetic parameters of KNP breeds. Kim et al. [16] conducted the first study estimating the genetic parameters for litter size in KNPs, reporting heritability estimates of 0.40 for total number born (TNB) and 0.47 for number born alive (NBA). Although KNP populations are relatively closed, potentially indicating lower genetic diversity, researchers noted that there is still high genetic variance within the population, particularly in terms of litter size.

Sohn et al. [17] established the G-band marker and analyzed the pattern of heterochromatin using the GTG-banding technique for karyotyping KNPs. They also examined the distribution pattern of nucleolus organizer regions (NORs) on chromosomes using the AgNOR staining

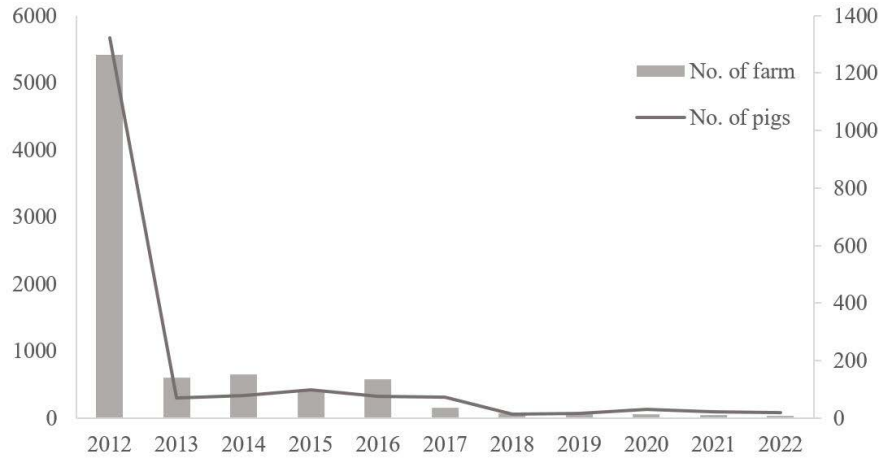

Fig. 1. Distribution history of Jeju native black pigs in Jeju Special Self-Governing Province (2012~2022). Adapted from Jeju Special Self-Governing Province National Institute of Animal Science [28] with permission of author.

https://doi.org/10.5187/jast.2023.e120

technique.

Inbreeding depression, a phenomenon in which individuals exhibit reduced fitness due to close relatives mating, has been documented in various organisms. KNPs are the only domestic pig breed in Korea and are maintained in small populations. Kim et al. [16] analyzed the inbreeding coefficients, genetic parameters, and the effects of inbreeding depression on TNB and NBA of KNPs held at the NIAS, utilizing the data from 2,806 KNPs and 303 sows as well as 483 reproduction records. They reported that both TNB and NBA maintained a high degree of heritability. The inbreeding coefficients steadily increased from 1998 to 2017–2018. However, there was no observed decrease in the abilities related to each trait when comparing 2017–2018 to 1998. The increase in the inbreeding coefficient was associated with significant inbreeding depression in TNB, but there was no significant inbreeding depression observed in NBA. They also reported that there were some effects of inbreeding depression on the litter size of KNPs, but there was no clear phenotypic reduction observed over the generations, indicated that inbreeding depression can be overcome by the high genetic effects [16].

Choi et al. [11] compared the growth rates of three-way crossbred pigs using Duroc pigs (Landrace × Yorkshire × Duroc [LYD]) and other three-way crossbred pigs using Woori black pigs (WBP) as the terminal sires (Landrace × Yorkshire × Woori black pig [LYW]). They found no significant differences in growth performance between these groups. Additionally, the LYW crossbred pigs exhibited higher backfat thickness and better meat yield in the Boston butt, highlighting the value of using WBPs as terminal sires.

The results suggest that, currently, the growth performance of KNPs may not surpass that of LYD three-way crossbred pigs. However, it will be possible to enhance productivity in the KNP industry through ongoing breeding programs focused on improving litter size, growth rates, and meat yields, combined with systematic feed and nutrition management. The enhanced productivity of the KNP industry is also expected to contribute to promoting and showcasing the excellence of the KNP breed internationally by maximizing differentiation in taste and nutritional components.

GROWTH

The comparison of average daily gain (ADG) showed no significant differences between males and females [2]. ADG is 390 to 400 g, and it takes around 200 to 210 days to reach a weight of 70 kg. When compared to the Yorkshire, Landrace and Duroc three-way crossbreed (YLD), the growth of KNPs is more than one month slower, with a finishing weight of 110 kg reached at approximately 170 days (Table 1).

Kim et al. [18] compared the growth performance and nutrient digestibility of Korean native

Table 1. Growth performance of Korean native pigs

Classification	Female	Male
Initial (d)	85 ± 13	87 ± 13
Final (d)	210 ± 13	204 ± 32
Initial weight (kg)	21.2 ± 6.6	22.1 ± 6.8
Final weight (kg)	70.0 ± 6.0	67.7 ± 12.1
Average daily gain (g)	390 ± 56	389 ± 80
Feed conversion ratio	4.56 ± 0.3	4.5 ± 0.22
Final backfat thickness (mm)	2.64 ± 0.28	2.11 ± 0.37

Adapted from National Institute of Animal Science [2] with permission of author.

piglets and crossbred piglets. The overall results indicated that the growth performance of CBs was better than KNPs. The average weaning weight of KNPs was 3.7 kg, while that of CBs was 5.09 kg. On the 21st day after birth, the average weights were 6.46 kg for KNPs and 9.33 kg for CBs. They found that ADG (0 to 21 d) differed by approximately 19.5%, resulting in about an 18.9% difference in feed efficiency, which means the growth performance of KNPs is approximately 20% lower than CBs.

In the comparison of nutrient digestibility, CBs showed higher digestibility rates for dry matter (DM), gross energy (GE), crude protein (CP), and phosphorus (P) compared to KNPs. KNPs had lower plasma amylase activity, which could lead to impaired carbohydrate digestion. The deficiency of amylase enzyme may interfere with nutrient absorption and result in reduced growth rates. Additionally, the lower weaning weight of KNPs might indicate less developed intestines, making it challenging for them to digest and absorb nutrients effectively and lead to slower growth rates [19,20].

To improve economic traits such as growth rate and litter size in Jeju native pigs and to enhance their productivity, the NIAS has developed new pig breeds, namely Chuk-jin Duroc pigs and Woori black pigs. Chuk-jin Duroc pigs are a unique domestic breed in Korea, while WBPs are the result of crossing KNPs with Duroc pigs [11]. Chuk-jin Duroc pigs achieve an ADG of approximately 700 g, and they reach 110 kg at around 160 days of age. This is a significant improvement in growth rate compared to Jeju native black pigs. The time required for Chuk-jin Duroc pigs to reach 70 kg is approximately 125 days, showing a 38% faster growth rate compared to Jeju native black pigs (Fig. 2).

Kim et al. [20] compared the growth performance and related gene expression of muscle and fat from LYD and WBP. A total of 24 pigs (12 LYD and 12 WBP) were used in the study. They presented significant results regarding the ADG between WBP and LYD. LYD showed an ADG that was 21% higher than WBP, without significant differences in daily feed intake. Comparing this to the growth data from the NIAS, the ADG increased by approximately two-fold from 390 g to 768 g, confirming growth improvements in WBP. However, it is still evident that the growth rate of LYD pigs is higher than that of WBPs (Table 2).

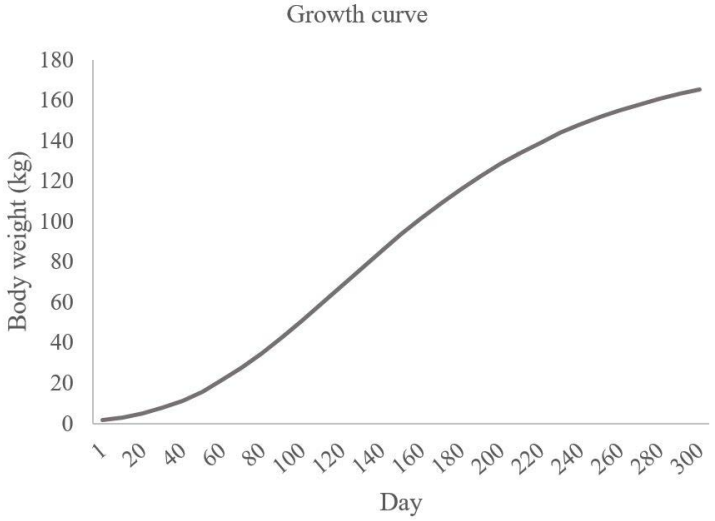

Fig. 2. Growth curve of Chukjin-Duroc. Adapted from Jeon et al. with permission of National Institute of Animal Science [29] with CC-BY-NC-ND.

https://doi.org/10.5187/jast.2023.e120

Table 2. Comparison of growth performance between LYD (Landrace×Yorkshire×Duroc) and WBP (Woori black pig)

Classification	LYD	WB	*p*-value
Initial weight (average 65 days, kg)	26.20 ± 0.60	24.86 ± 2.40	0.097
Final weight (average 155 days, kg)	124.37 ± 2.37	120.63 ± 0.95	0.126
Average daily gain (g)	975.70 ± 105.15	768.49 ± 69.17	0.001
Daily feed intake (g)	2,736.04 ± 120.35	2,736.52 ± 131.72	0.974

Adapted from Kim et al. [20] with CC-BY-NC.

REPRODUCTION

Since the 1980s, efforts have been made to restore and preserve the genetic diversity of KNP breeds while also conducting research to improve the economic viability of domestic pigs [5,10]. Specifically, important maternal reproductive traits in terms of economic value include parity, litter size, birth weight, number weaned and weaning weight [21,22].

According to statistics from the NIAS (1998-2012), KNPs have an average TNB of 6.8 piglets, an average litter birth weight of 7.1 kg, an average of 5.7 piglets at 21 days of age, and an average litter weight of 21.3 kg at 21 days of age (Fig. 3). It can be seen that the productivity of KNPs is significantly lower than that of CBs, which have litter sizes of 10 to 12 piglets. The average birth weight of piglets is 1.04 kg, which is not significantly lower compared to the three-way crossbred piglets. However, at 21 days of age, the average weight of KNP piglets is 3.7 kg, indicating a relatively slow rate of weight gain.

Kim [23] investigated the changes in CB by maternal breed and parity within the seedstock population of Jeju Island (JPLI). Landrace, Yorkshire and Duroc pigs exhibited an average TNB of around 11 piglets, whereas Jeju native pigs had a lower average TNB of 7.5 piglets and a decreasing TNB after the 3rd parity. Landrace and Yorkshire pigs showed a similar decreasing trend in litter size after the 4th parity, while Duroc pigs exhibited an increase up to the 5th parity but a sharp decrease after the 6th parity (Fig. 4).

Jeju native pigs showed a gradual decline after the 3rd parity. Jeju native pigs can be subject to

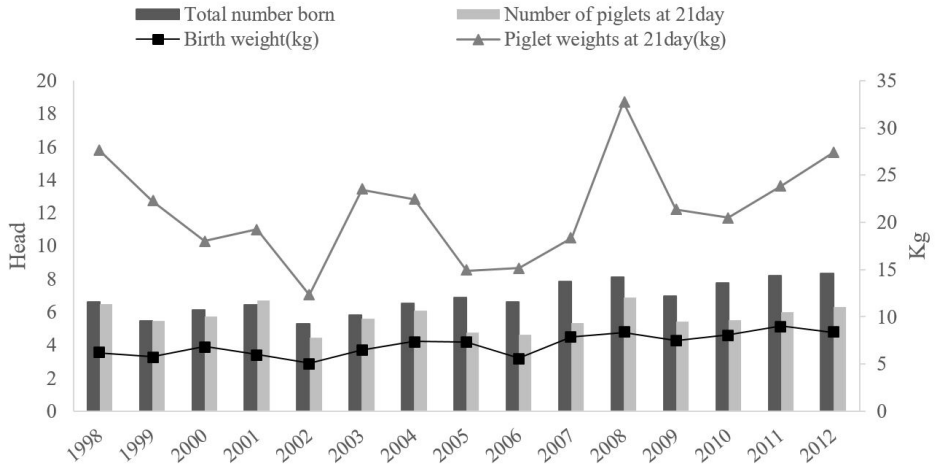

Fig. 3. Reproductive performance of Korean native pigs by year. Adapted from National Institute of Animal Science [2] with permission of author.

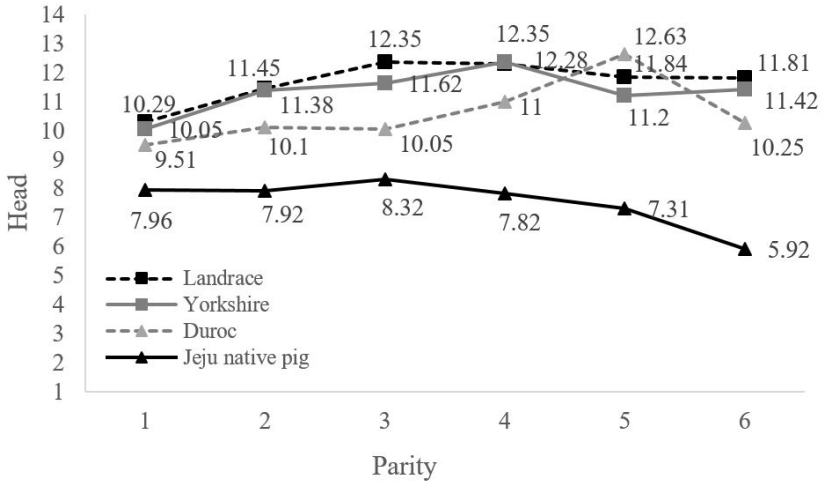

Fig. 4. Total number born by breed and parity. Adapted from Kim et al. [23] with CC-BY-NC-ND.

long-term inbreeding and inbreeding depression due to their geographical and subpopulation isolation [16]. The change in litter size of Jeju native pigs is attributed to high inbreeding leading to inbreeding depression for population maintenance. When compared to the decrease in total litter size beyond the 6th parity in multiparous breeds [24], it is evident that sow productivity is low, indicating the need for breed improvements to enhance their economic efficiency.

OTHER

Recent efforts to industrialize Jeju native black pigs involve not only introducing a multi-way crossbreeding system for meat quality improvement, but also an active industrial expansion driven by increasing the demand for black pig products [25].

Meat color is a quantification of the difference in the color of meat, and it is related to freshness. Fresh meat exhibits a light red color, which contributes to consumer preference. CIE L*, a*, and b* system is normally used for objective color scores. Lightness is quantified with a higher value indicating closer to white, and redness is quantified with a higher value indicating it is a better meat color. These two factors significantly influence meat color. A study comparing meat color between Landrace pigs and KNPs found that KNP meat had a lighter and redder color (Landrace: L-value and a-value were 42.26 and 3.38, respectively, whereas they were 45.35 and 10.84 in KNPs) [26].

Berkshire pigs are famous for their meat quality. In the United States, the American Berkshire Association operates a 100% Berkshire certification program, which has been very helpful for exports to Japan. Through bilateral FTAs, China, Japan, and Korea are emerging markets for US pork exports [1,27]. Korea should also activate an association for KNPs and establish a certification program simultaneously with their improvement efforts. This will help distinguish genuine certified farms from those producing unverified black pigs, ensuring that the market functions properly without distortion.

When looking at the trend of pig prices, the average pig price has been on the rise since 2020, with Jeju-produced pigs trading at prices about 1,000 to 1,300 KRW per kilogram higher than the national average until 2021. However, in September 2022, the trading price was about 2,600 KRW per kilogram higher (Fig. 5).

https://doi.org/10.5187/jast.2023.e120

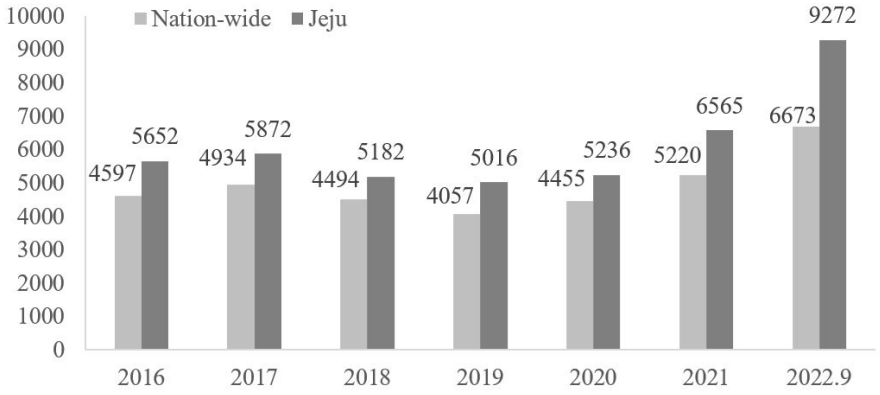

Fig. 5. Pork price trends (Korean won/kg). Adapted from Jeon et al. [30] with permission of Korea Research Institute for Local Administration.

In the future, swine producers are likely to avoid raising KNPs due to various issues such as the difficulty of entering the livestock industry, environmental concerns, odor complaints, and concerns about KNP productivity and price competitiveness. To address these issues, research has been conducted to improve the economic viability of KNPs [5,10].

CONCLUSION

KNPs hold historical significance in Korea. It is essential to maintain this particular breed for genetic diversity and species preservation. Unfortunately, there is still a long way to go for the improvement of KNPs. It is crucial to acknowledge the current challenges, identify the issues, and dedicate efforts wholeheartedly to the breed's improvement. Each section of this comprehensive review will play an important role in integrating related research and data into the overall findings. In-depth discussions on the genetic diversity, productivity, genetic conservation, ecological roles, and sustainability of KNPs will be crucial for the future of KNP business.

REFERENCES

1. Oh SH, See MT. Pork preference for consumers in China, Japan and South Korea. Asian-Australas J Anim Sci. 2012;25:143-50. https://doi.org/10.5713/ajas.2011.11368
2. National Institute of Animal Science. Breeding of Korean native pig. Wanju: National Institute of Animal Science; 2013.
3. Seo JK, Eom JU, Yang HS. Comparison between Berkshire and crossbreed on meat quality, and investigation of the relationship with fatty acid composition and meat quality. J Anim Sci Technol. 2023;65:1081-93. https://doi.org/10.5187/jast.2023.e21
4. Kim KS, Choi CB. Genetic structure of Korean native pig using microsatellite markers. Korean J Genet. 2002;24:1-7.
5. Kim TH, Kim KS, Choi BH, Yoon DH, Jang GW, Lee KT, et al. Genetic structure of pig breeds from Korea and China using microsatellite loci analysis. J Anim Sci. 2005;83:2255-63. https://doi.org/10.2527/2005.83102255x
6. Han GP. A study on free amino acid content and preference for Korean native and hybrid pork.

Food Serv Ind J. 2009;5:127-48. https://doi.org/10.22509/kfsa.2009.5.2.007
7. Jin SK, Kim IS. Physiochemical and sensory quality characteristics of branded pork circulating in the meat shop. J Korean Soc Int Agric. 2001;13:149-57.
8. Yang SJ, Kim YK, Hyon JS, Moon YH, Jung IC. Amino acid contents and meat quality properties on the loin from crossbred black and crossbred pigs reared in Jejudo. Korean J Food Sci Anim Resour. 2005;25:7-12.
9. Kim GW, Yoo JY, Kim KJ, Lee JW, Kim YB, Min KH, et al. Analysis of carcass characteristics by gender and carcass grades of Jeju native pigs. J Anim Sci Technol. 2010;52:313-8. https://doi.org/10.5187/jast.2010.52.4.313
10. Kim J, Cho S, Caetano-Anolles K, Kim H, Ryu YC. Genome-wide detection and characterization of positive selection in Korean native black Pig from Jeju Island. BMC Genet. 2015;16:3. https://doi.org/10.1186/s12863-014-0160-1
11. Choi YH, Min YJ, Jung HJ, Jeong YD, Kim JA, Cho ES, et al. Effects of Woori black pig sire on growth performance, body shape, and retail cut yield of crossbred pigs. J Korea Acad Ind Coop Soc. 2020;21:432-9. https://doi.org/10.5762/KAIS.2020.21.9.432
12. Park J, Lee SM, Park JY, Na CS. A genome-wide association study (GWAS) for pH value in the meat of Berkshire pigs. J Anim Sci Technol. 2021;63:25-35. https://doi.org/10.5187/jast.2021.e17
13. Hwang IH, Park BY, Cho SH, Kim JH, Choi YS, Lee JM. Identification of muscle proteins related to objective meat quality in Korean native black pig. Asian-Australas J Anim Sci. 2004;17:1599-607. https://doi.org/10.5713/ajas.2004.1599
14. Kim DH, Seong PN, Cho SH, Kim JH, Lee JM, Jo C, et al. Fatty acid composition and meat quality traits of organically reared Korean native black pigs. Livest Sci. 2009;120:96-102. https://doi.org/10.1016/j.livsci.2008.05.004
15. Rural Development Administration. Traditional knowledge compilation: gene resources part I. Suwon: RDA; 1997. p. 9.
16. Kim YS, Cho KH, Lee MJ, Kim JA, Cho ES, Hong JK. Effects of inbreeding depression on litter size of Korean native pig. J Korea Acad Ind Coop Soc. 2019;20:514-20. https://doi.org/10.5762/KAIS.2019.20.6.514
17. Sohn SH, Kweon OS, Baik KH, Jung W, Cho EJ, Kang MY. G-, C-, and NOR-banding of Korean native pig chromosomes. J Anim Sci Technol. 2003;45:901-10. https://doi.org/10.5187/JAST.2003.45.6.901
18. Kim KH, Lohakare JD, Sen S, Ingale SL, Singh NK, Park CK, et al. Comparison of growth performance, nutrient digestibility, blood metabolites and carcass traits in Korean native and crossbred weaning piglets. Anim Nutr Feed Technol. 2011;11:159-67.
19. Upadhaya SD, Seok WJ, Kumar SS, van der Veen RH, Kim IH. Marine derived Ca-Mg complex supplementation basal diet during four subsequent parities improved longevity and performance of sows and their litters. J Anim Sci Technol. 2023;65:562-78. https://doi.org/10.5187/jast.2022.e121
20. Kim B, Min Y, Jeong Y, Ramani S, Lim H, Jo Y, et al. Comparison of growth performance and related gene expression of muscle and fat from Landrace, Yorkshire, and Duroc and Woori black pigs. J Anim Sci Technol. 2023;65:160-74. https://doi.org/10.5187/jast.2022.e93
21. Cho KH, Kim MJ, Lee IJ, Kim IC, Jeon GJ. Genetic correlation of reproductive trait in pigs by parity. J Anim Sci Technol. 2008;50:457-64. https://doi.org/10.5187/jast.2008.50.4.457
22. Choi TJ, Kwak CU, Song KB, Na JS, Choe HS. Analysis of environmental effect on reproductive trait (Litter size at birth and weaning rate) in swine. Reprod Dev Biol. 2010;34:27-32.

https://doi.org/10.5187/jast.2023.e120

23. Kim CN. Effects of Estrogen receptor (ESR) and properdin (BF) genotypes on litter size of pig breeder population in Jeju Institute [Master's thesis]. Jeju, Korea: Cheju National University; 2007.
24. Matheson SM, Walling GA, Edwards SA. Genetic selection against intrauterine growth retardation in piglets: a problem at the piglet level with a solution at the sow level. Genet Sel Evol. 2018;50:46. https://doi.org/10.1186/s12711-018-0417-7
25. Han SH, Shin KY, Lee SS, Ko MS, Jeong DK, Jeon JT, et al. Effects of ADCYP1R1, FABP3, FABP4, MC4R, MYL2 genotypes on growth traits in F2 population between Landrace and Jeju native black pig. J Anim Sci Technol. 2008;50:621-32. https://doi.org/10.5187/JAST.2008.50.5.621
26. Kim CW, Yeo JS, Cho KK, Jin SK, Oh MG, Park JK, et al. Analysis of species-specific genetic marker and its relationship with meat quality in Korean native pig. J Anim Sci Technol. 2001;43:789-802.
27. Oh SH, Whitley NC. Pork production in China, Japan and South Korea. Asian-Australas. J Anim Sci 2011;24:1629-36. https://doi.org/10.5713/ajas.2011.11155
28. Jeju Special Self-Governing Province National Institute of Animal Science. Jeju black pig [Internet]. 2023 [cited 2023 Oct 23]. https://www.jeju.go.kr/livestock/content/blackpig.htm
29. National Institute of Animal Science. Seedstock developing specification management guidelines: Chukjin-Duroc, Woori-HeukDon. Cheonan: National Institute of Animal Science; 2016.
30. Jeon DW, Choi IS, Jang IS. Analysis of regional economic effects of pig farming industry in Jeju. Wonju: Korea Research Institute for Local Administration; 2022.