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The breeding history and commercial development of the Korean native chicken

S. JIN[1], D.D. JAYASENA[2], C. JO[3] and J.H. LEE[1]*

[1]Division of Animal and Dairy Science, Chungnam National University, Daejeon 34134, Korea; [2]Department of Animal Science, Uva Wellassa University, Badulla 90000, Sri Lanka; [3]Department of Agricultural Biotechnology, Center for Food and Bioconvergence, and Research Institute of Agriculture and Life Science, Seoul National University, Seoul 08826, Korea
*Corresponding author: junheon@cnu.ac.kr

The Korean native chicken (KNC) is believed to have existed in the Korean Peninsula more than 1,400 years ago. Since then, KNC have been bred only by private farmers in rural areas of Korea. In 1994, a KNC conservation program was established by the Korean government and, as a result, five lines were restored. KNC are considered to have a unique taste and texture that is more attractive to Korean consumers than meat from commercial broilers. However, the price of KNC is relatively high, which is mainly due to the breed's low growth rate, hence the limitations for industrial applications. In addition, their unique taste and texture in comparison with that of other broilers has been evaluated by scientists over the past few years. The general composition, physiochemical traits, content of taste-active and endogenous bioactive compounds and sensory quality of KNC meat, as well as breeding history are reviewed in this paper. The information from this review can be used for the development of commercial KNC breeds and can be applied to models for the commercialisation of native chicken breeds in developing countries.

Keywords: Korean; meat quality; performance; phenotype; commercialisation

Introduction

Recently there has been much research attention focused on the conservation of animal genetic resources and the maintenance of genetic biodiversity. In the case of domestic livestock, the Domestic Animal Diversity Information Service (DAD-IS) of the FAO has been developed for the documentation of the statistics and characteristics of local breeds of animals, including endangered species (http://dad.fao.org/). As a result of such initiatives, a diverse collection of animal genetic resources and detailed management regimes have been regarded as high priorities for many national governments. Within this context, there is an assumption that the recent high incidence of diseases, including avian influenza, is related to high genetic homozygosity in commercial chickens, even though

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their meat production and growth performance is high. In this regard, conservation of local animal breeds and varieties, which may have natural disease resistance, is very important for all animal-based industries, including poultry. Additionally, as the world population is projected to reach 10 billion within the current century, conservation of the diverse animal genetic resources is ultimately needed for the sustainable supply of animal protein sources.

The consumption of Korean native chicken (KNC) has continuously increased among Korean consumers who are seeking better taste and healthier rearing conditions of their livestock. For many, the activity of raising KNC is not only for the conservation of animal resources but also for the provision of primary business income. KNC have been classified into two types; the original KNC that has inhabited the Korean Peninsula for centuries, and imported chicken breeds introduced in the 1960s and 70s and their progeny since that time, which are called 'adapted KNC'.

The chicken meat market in Korea is primarily based on whole chicken (~1.5 kg is standard), and is different from the cut up meat market in many other countries. For this reason, the slaughter age for poultry in Korea tends to be earlier than that in Western countries. KNC became almost extinct during the Korean War, and this, combined with the breed's characteristically slow growth, has limited commercialisation, confining KNC to small-scale production until the 1990s. However, in 1992, the National Livestock Research Institute (currently the National Institute of Animal Science; NIAS) in Korea launched a project regarding maintenance of purebred KNC lines and the promotion of commercial KNC production and distribution. As a result, KNC currently constitutes approximately 10% of total poultry consumption, and the number of birds reached 3.6 million in 2014. This number is expected to steadily increase in the near future (Korean Native Chicken Association, http://www.knca.kr/).

Native chicken consumption has increased in countries in Asia, such as Taiwan, Japan, Thailand, and China. In the case of Taiwan, native chicken has more than 50% of the market share of total chicken consumption (Lee, 2006; Chumngoen and Tan, 2015). In Japan, customers want differentiated chicken meat and, as a result, approximately 150 Japanese chicken brands have been produced, of which 46 have been developed using local native breeds. The meat from these Japanese native chicken brands is approximately two to five times more expensive than those from the commercial broilers. However, these are regarded as regional specialties, and demand is increasing (Yukio, 2005). In China, native chicken meats constitute 20% of the total poultry meat market, and are also more expensive (Tang *et al.*, 2009).

This review covers the past half century of KNC history to give directions for science and industry regarding using native chicken breeds, not only for Korea but also to meet other Asian consumers' demands.

History of KNC

There is controversy surrounding the origin of domesticated chicken worldwide based on reports using mitochondrial DNA displacement (mtDNA D) loop variation and microsatellite (MS) marker analyses. DNA sequence analysis has been used for investigating the origin of the domestic chicken. Until recently, major scientific opinion was that the red jungle fowl (*Gallus gallus*) had been the main contributor to the genetic makeup of the domestic chicken, which has been supported by mtDNA analysis, MS marker analysis (Fumihito *et al.*, 1996; Hillel *et al.*, 2003) and whole-genome resequencing data (Rubin *et al.*, 2010). However, multiple domestication events have been suggested by mtDNA data (Liu *et al.*, 2006; Miao *et al.*, 2013). Moreover, based on the analysis of the gene governing yellow-coloured skin, BCDO2, both red jungle fowl and grey jungle fowl are related to the domestic chicken (Eriksson *et al.*, 2008).

The historical record for KNC was first established when chicken bones from the Stone Age were excavated in North Korea. In addition, eggs were identified in Cheonmachong, an ancient tomb in Gyeongju, South Korea, dating to approximately 400 to 500 C.E.. Based on excerpts from the Samkukji Wheezie Dongijeon, an ancient book written in the middle of third century CE, there were beautiful long-tailed chickens in Korea with tails approximately 150 cm in length. Various evidence has indicated that the KNC originated about 2,000 years ago, either from China or directly from India or Southeast Asia.

In recent years, research on the origin of KNC has been mainly carried out using the D-loop region in mtDNA. Haplotype analysis using the mtDNA D-loop region suggested that KNC are closely related to red jungle fowl (Hoque *et al.*, 2009). Based on the results of Cho *et al.* (2011) using the mtDNA D-loop variation, at least five maternal lineages, which do not share a common ancestor, were derived from China and transferred to Japan. Based on the results of phylogenetic analysis using whole mitochondrial genome sequencing from five KNC lines, the breed has multiple maternal origins from Myanmar, Japan, and China, and these results were in agreement with other historical evidence (Kwak *et al.*, 2014).

DEVELOPMENT OF FIVE LINES OF KNC

The population of KNC dramatically decreased after the Korean War and, due to the importation of exotic breeds, it remained the only available in remote rural areas. Since the end of the 1970s, NIAS started the KNC restoration project, initially with a collection of the breeds. In the 1980s, the national income of Korea increased which lead to higher interest in the rearing of KNC, even in private farms. These developments led to the rise of KNC in the revitalised local poultry industry. Since 1992, project has focused on the refinement of physical characteristics. In 1994, an official nationwide 'project for generating high-quality and commercially viable KNC' was launched with the help of the Korea Poultry Association. This project focused on the restoration and establishment of lines and production systems for superior commercial KNC. This project continued for 15 years, until 2007. As a result, five KNC lines were established based on feather colour, body shape, and external appearance. These lines, namely White (Baeksaek Jarae-jong), Black (Heuksaek Jaerae-jong), Grey (Hoegalsaek Jaerae-jong), Yellow (Hwanggalsaek Jaerae-jong), and Red KNC (Jeokgalsaek Jaerae-jong) have been registered with the DAD-IS system of FAO (http://dad.fao.org/).

MORPHOLOGICAL CHARACTERISATION OF KNC

Based on the KNC restoration project, continuous selection and culling has been performed and the five lines fully established. The general characteristics of a KNC are a red-coloured single comb, rectangular body shape, yellow skin and grey shanks. The mature body weight is 2.5 to 3.1 kg for males and 1.6 to 2.0 kg for females. Hens produce a light brown egg shell (http://dad.fao.org/). Previously, the characteristics of 11 body parts were documented for these five lines of KNC (Sang *et al.*, 2006). For more than 20 years, birds with undesirable characteristics have been culled, and true-breeding types generated.

Genetic characterisation of KNC

The first cytogenetic report for KNC was started in 1989 by analysing the karyotype of males and females (Chung *et al.*, 1989). Following this, chromosomal length and characteristics of KNC and White Leghorn chickens were compared to investigate structural characteristics. In addition to cytogenetic characteristics, documentation of morphological characteristics has also been performed (Yeo, 1992).

Since the 1990s, DNA markers have been applied for the investigation of genetic characteristics only observed in the KNC breeds. Eight blood protein and enzyme loci were compared with those of other native and commercial breeds. Results suggested that KNC were more closely related to New Hampshire, Plymouth Rock, and Rhode Island Red breeds than to the White Leghorn (Lee *et al.*, 1996a). Using DNA fingerprinting, the estimation of genetic relationships with other exotic breeds and genetic variations within the population suggest that KNC has large genetic diversity. Results confirmed that KNC was closely related to Rhode Island Reds than to White Leghorn and Cornish breeds (Lee *et al.*, 1996b).

Based on increased household income and consumer preference for high-quality livestock products, the demand for KNC has gradually increased. Along with increased demand, identification of breeds and individuals has become more important. Since the year 2000, studies using MS markers have been conducted in order to investigate the identification of KNC-specific markers. This has been done for the purpose of individual and breed identification, which can be used for the traceability system (Kong *et al.*, 2006; Choi *et al.*, 2012; 2015; Seo *et al.*, 2013; 2015a; Suh *et al.*, 2014). In addition, DNA markers in the major histocompatibility complex (MHC) were investigated for their possible roles in disease resistance. In this regard, MS marker, *LEI0258*, located in the MHC region, has been investigated in KNC and exotic breeds, and results suggested that this marker can be used for breed discrimination (Jung *et al.*, 2009; Hoque *et al.*, 2011).

In addition, mtDNA analysis has been used for the identification of genetic relationships within KNC due to their high polymorphism and maternal inheritance (Niu *et al.*, 2002). A study using mtDNA in KNC was begun based on analysis of the variation in the cytochrome C oxidase I (*COI, cox1*) gene by Jin *et al.* (2009). *COI* has been widely used for DNA barcoding systems in various species (Hebert *et al.*, 2003; Meusnier *et al.*, 2008). mtDNA D-loop region in KNC has been used for phylogenetic analysis and discrimination between breeds (Hoque *et al.*, 2009; 2013a; Sultana *et al.*, 2012). Moreover, phylogenetic analysis have suggested that KNC has similar genetic variations with the native chickens in China, and has possibly five different maternal origins (Cho *et al.*, 2011) and the whole mitochondrial genome sequencing results have indicated that KNC were derived from the multiple genetic origins of chickens (Kwak *et al.*, 2014).

Recently, many molecular genetic technologies have been developed, and these technologies are being applied to the identification and molecular characterisation of KNC. Copy number variation (CNV) as structural variation was investigated in KNC (Cho *et al.*, 2014) and whole genome sequencing was performed on five lines and aligned with reference genome sequences in the database in order to identify novel SNPs and InDels (Kwak *et al.*, 2014; Seo *et al.*, 2014). In particular, Kwak *et al.* (2014) investigated highly variable regions for auditory sense, growth rate, and egg shell traits and identified olfactory receptor-related genes in five KNC lines. In addition, the first linkage (genetic) map for KNC was constructed using 131 MS and eight SNP markers in 2015. The length of linkage map was 2,729.4 cM, and the average map distance between markers was 19.64 cM. The marker order and genetic distances are similar to those obtained from previous linkage map results, and identified average number of alleles, heterozygosity values, and polymorphic information content (PIC) values, which were 5.5, 0.63, and 0.58, respectively, indicating that these markers have sufficient polymorphism to be used for the construction of genetic maps (Seo *et al.*, 2015b).

Exterior phenotypic characteristics investigated feather development (fast and slow) and colours, as these are a primary trait for sex-linked inheritance and widely used for autosexing breeds. These were compared for KNC, black Cornish, Rhode Island Red and Red KNC breeds, which have both fast- and slow-feathering phenotypes and genotypes and thus can be used for autosexing (Sohn *et al.*, 2012). In addition, feather development has not been shown to affect production traits (Sohn *et al.*, 2013).

Five lines of KNC were classified according to feather colour. Initially, genome wide association studies (GWAS) were carried out using 60K SNP chips for the identification of variations in feather colour. Twelve significant genes were identified, including pigment-related *AKT7*, *PAP2*, *DDX6*, and *KRT7* (Park *et al.*, 2013). Moreover, the variations of the chicken *MC1R* gene were identified and their relationships with feather colours were investigated (Hoque *et al.*, 2013b). This gene has an effect on KNC shank colour, especially the yellowness (b*) (Jin *et al.*, 2014) and controls eumelanin and pheomelanin and affects skin and feather colours in various species (Andersson, 2003; Klungland and Våge, 2003; Lin and Fisher, 2007).

Studies on quantitative trait loci (QTLs), which affect various economic traits in KNC, have been carried out using genome-wide mapping technologies. Seo *et al.* (2015c) identified QTL regions for meat quality-related traits of KNC, and Cahyadi *et al.* (2016) identified QTLs that affect weekly body weight- and growth.

In the future, these findings can be used for the selection of desired traits and development of breeding strategies in KNC.

Development of the commercial KNC

Along with those examining the maintenance and breeding of pure KNC lines, many studies have examined the development of commercial lines, which has a higher growth rate and better meat quality. In the 1990s, heterosis effects were investigated by crossings between KNC and exotic breeds. Kang *et al.* (1997a) investigated hatchability, growth and heterosis for KNC crossings using Rhode Island Red as the female line. All of these crosses had higher 20-week body weights than pure lines. As for laying performance, age at point of lay was significantly shorter in crosses, and survival and weekly body weights were higher than those of the pure breeds (Kang *et al.*, 1997b). Growth performance for the three-way cross-breeds, wherein the male line was the Cornish breed and the female line was KNC × Rhode Island Red, were investigated (Kang *et al.*, 1998a; 1998b). Since 2000, original and adapted KNC breeds have been widely used for diverse crossbreeding experiments, the focus of which has been to increase meat and egg production and to improve meat qualities (Park *et al.*, 2010; 2011; Kang *et al.*, 2010; Lee *et al.*, 2013; 2014). Based on these diverse experiments, NIAS has announced the development of a commercial KNC breed, called '*Woorimatdak.*' This breed was developed based on the three-way crosses and is currently available in the Korean market.

Meat quality of KNC

Typically, meat from indigenous chickens including KNC has a unique taste and texture that attracts domestic consumers more than meat from commercial broilers (CB) (Jayasena *et al.*, 2013). This has been carefully evaluated via scientific analyses over the past few years. *Table 1* summarises the findings of such studies related to general composition, physicochemical traits, and taste-active and endogenous bioactive compound content of breast and thigh/leg meat from KNC and CB.

GENERAL COMPOSITION AND PHYSICOCHEMICAL TRAITS OF KNC MEAT

Several studies have shown that KNC has a better general composition than CB, irrespective of the meat cut (*Table 1*; Kweon *et al.*, 1995; Choe *et al.*, 2010; Jeon *et al.*, 2010; Jung *et al.*, 2011; Jayasena *et al.*, 2013). Regarding meat colour, the L* (lightness) value of breast meat was significantly higher in KNC, but is higher in thigh meat from CB (*Table 1*). A significantly higher a* (redness) value was seen in the thigh meat of KNC compared to CB (*Table 1*; Choe *et al.*, 2010; Jeon *et al.*, 2010; Jung *et al.*, 2011; Jayasena *et al.*, 2013). However, moisture, crude ash content (Kweon *et al.*, 1995; Choe *et al.*, 2010; Jeon *et al.*, 2010; Jung *et al.*, 2011) and water-holding capacity (Jung *et al.*, 2011; Jayasena *et al.*, 2013) of meat were comparable between the two breeds, regardless of meat cut. In addition, breast and thigh meat of KNC had significantly lower pH values than CB (*Table 1*; Kweon *et al.*, 1995; Choe *et al.*, 2010; Jeon *et al.*, 2010; Jung *et al.*, 2011; Jayasena *et al.*, 2013). For meat texture, KNC had higher cohesiveness, gumminess, and chewiness values (Choe *et al.*, 2010; Jung *et al.*, 2011) as well as hardness values (Choe *et al.*, 2010) than CB.

TASTE-ACTIVE AND ENDOGENOUS BIOACTIVE COMPOUND CONTENTS OF KNC MEAT

KNC has significantly higher content of taste-active compounds than CB (Choe *et al.*, 2010; Jeon *et al.*, 2010; Jung *et al.*, 2011; Jayasena *et al.*, 2013, 2014b), except for cysteine and oleic acid. Ahn and Park (2002) demonstrated that KNC (2.68 to 4.55) had a higher ratio of tasty to bitter amino acids than CB (1.60 to 3.64). Based on these results, Jayasena *et al.* (2014b) suggested that the higher levels of taste-related compounds present in KNC meat than in CB meat resulted in its unique taste. However, it was reported that the availability of these taste-active compounds in KNC meat is governed by several factors, including line and sex (Jung *et al.*, 2013), age, meat cut and cooking process (Jayasena *et al.*, 2015c).

Recently, Jung *et al.* (2013) and Jayasena *et al.* (2014a; 2015a; 2015b) provided useful information regarding the availability and amounts of bioactive compounds in KNC meat and some of the determinants that affect these compounds. The studies showed that KNC meat contained a considerable amount of endogenous bioactive compounds such as carnosine, anserine, creatine, betaine and carnitine, which is dependent on the age and line of KNC, meat cut, sex and cooking process (Jung *et al.*, 2013; Jayasena *et al.*, 2014a; 2015a; 2015b). Jayasena *et al.* (2015a) conducted an in-depth study revealing that meat from KNC was a significantly better source of carnosine, anserine, and carnitine than that from CB, which has a higher content of betaine. The effect of age of KNC on the availability of these compounds was only observed for betaine (Jayasena *et al.*, 2014a).

SENSORY QUALITY OF KNC MEAT

Several studies have shown that sensory characteristics such as colour, odour, taste, texture, and overall acceptance did not differ substantially between KNC and CB (Choe *et al.*, 2010; Jeon *et al.*, 2010; Jayasena *et al.*, 2013). However, the thigh meat from KNC scored significantly higher values for odour, taste, and overall acceptance than CB (Jung *et al.*, 2011).

Conclusions

Various projects have examined the benefits of locally grown chicken in Korea and how these can be cross bred to provide commercial lines, whilst maintaining its unique characteristics and flavour. Using funding from the Korean government, a new 10-year research project, called the Golden Seed Project, has been launched in 2012 in order to develop and maintain basal breeding stocks in animals and plants. In livestock animals, this project only focuses on pigs and chickens. The ultimate goals for this project are to generate US $200 million income from the exportation of breeding stock (including plants and fisheries) until 2020 and US $300 million income by 2030. One of the main aims is to ensure that Korea becomes an important contributor to the global breed market. Once this is accomplished, 30% of chicken imports can be replaced by new, local chicken breeding stocks, and US $100 million income can be generated from the exportation of breeding stock by 2020. Therefore the use of KNCs is expected to be considerably profitable in the future (http://www.gsp.re.kr/).

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References

AHN, D.-H. and PARK, S.-Y. (2002) Studies on components related to taste such as free amino acids and nucleotides in Korean native chicken meat. *Journal of the Korean Society of Food Science and Nutrition* **31**: 547-552.

ANDERSSON, L. (2003) Melanocortin receptor variants with phenotypic effects in horse, pig, and chicken. *Annals of the New York Academy of Sciences* **994**: 313-318.

CAHYADI, M., PARK, H.-B., SEO, D.-W., JIN, S., CHOI, N., HEO, K.-N., KANG, B.-S., JO, C. and LEE, J.-H. (2016) Variance component quantitative trait locus analysis for body weight traits in purebred Korean native chicken. *Asian-Australasian Journal of Animal Sciences* **29**: 43-50.

CHO, C.-Y., LEE, P.-Y., KO, Y.-G., KIM, H.-K., PARK, M.-N. and YEON, S.-H. (2011) Multiple maternal origins of Korean native chicken based on the mtDNA D-loop variation. *Korean Journal of Poultry Science* **38**: 5-12.

CHO, E.-S., CHUNG, W.-H., CHOI, J.-W., JANG, H.-J., PARK, M.-N., KIM, N., KIM, T.-H. and LEE, K.-T. (2014) Genome-wide copy number variation in a Koran native chicken breed. *Korean Journal of Poultry Science* **41**: 305-311.

CHOE, J.H., NAM, K.C., JUNG, S., KIM, B., YUN, H.J. and JO, C. (2010) Differences in the quality characteristics between commercial Korean native chickens and broilers. *Korean Journal for Food Science of Animal Resources* **30**: 13-19.

CHOI, N.-R., HOQUE, M., SEO, D.-W., SULTANA, H., PARK, H.-B., LIM, H.-T., HEO, K.-N., KANG, B.-S., JO, C. and LEE, J.-H. (2012) ISAG-recommended microsatellite marker analysis among five Korean native chicken lines. *Journal of Animal Science and Technology* **54**: 401-409.

CHOI, N.R., SEO, D.W., JEMAA, S.B., SULTANA, H., HEO, K.N., JO, C. and LEE, J.H. (2015) Discrimination of the commercial Korean native chicken population using microsatellite markers. *Journal of Animal Science and Technology* **57**: 5.

CHUMNGOEN, W. and TAN, F.-J. (2015) Relationships between descriptive sensory attributes and physicochemical analysis of broiler and Taiwan native chicken breast meat. *Asian-Australasian Journal of Animal Sciences* **28**: 1028-1037.

CHUNG, S.B., CHEONG, E.W., PARK, E.W. and YEO, J.S. (1989) Studies on the genetic characters of Korean native fowl. *Korean Journal of Poultry Science* **16**: 209-217.

ERIKSSON, J., LARSON, G., GUNNARSSON, U., BED'HOM, B., TIXIER-BOICHARD, M., STRÖMSTEDT, L., WRIGHT, D., JUNGERIUS, A., VEREIJKEN, A. and RANDI, E. (2008) Identification of the yellow skin gene reveals a hybrid origin of the domestic chicken. *PLoS Genetics* **4**: e1000010.

FUMIHITO, A., MIYAKE, T., TAKADA, M., SHINGU, R., ENDO, T., GOJOBORI, T., KONDO, N. and OHNO, S. (1996) Monophyletic origin and unique dispersal patterns of domestic fowls. *Proceedings of the National Academy of Sciences of the United States of America* **93**: 6792-6795.

HEBERT, P.D., CYWINSKA, A. and BALL, S.L. (2003) Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London B: Biological Sciences* **270**: 313-321.

HILLEL, J., GROENEN, M.A., TIXIER-BOICHARD, M., KOROL, A.B., DAVID, L., KIRZHNER, V. M., BURKE, T., BARRE-DIRIE, A., CROOIJMANS, R. and ELO, K. (2003) Biodiversity of 52 chicken populations assessed by microsatellite typing of DNA pools. *Genetics Selection Evolution* **35**: 533-558.

HOQUE, M., JUNG, K.-C., PARK, B.-K., CHOI, K.-D. and LEE, J.-H. (2009) Genetic variability of mtDNA D-loop region in Korean native chickens. *Korean Journal of Poultry Science* **36**: 323-328.

HOQUE, M.R., LEE, S.H., JUNG, K.C., KANG, B.S., PARK, M.N., LIM, H.K., CHOI, K.D. and LEE, J. H. (2011) Discrimination of Korean native chicken populations using SNPs from mtDNA and MHC polymorphisms. *Asian-Australasian Journal of Animal Sciences* **24**: 1637-1643.

HOQUE, M.R., CHOI, N.R., SULTANA, H., KANG, B.S., HEO, K.N., HONG, S.K., JO, C. and LEE, J. H. (2013a) Phylogenetic analysis of a privately-owned Korean native chicken population using mtDNA D-loop variations. *Asian-Australasian Journal of Animal Sciences* **26**: 157-162.

HOQUE, M.R., JIN, S., HEO, K.N., KANG, B.S., JO, C. and LEE, J.H. (2013b) Investigation of MC1R SNPs and their relationships with plumage colours in Korean native chicken. *Asian-Australasian Journal of Animal Sciences* **26**: 625-629.

JAYASENA, D.D., JUNG, S., KIM, H.J., BAE, Y.S., YONG, H.I., LEE, J.H., KIM, J.G. and JO, C. (2013) Comparison of quality traits of meat from Korean native chickens and broilers used in two different traditional Korean cuisines. *Asian-Australasian Journal of Animal Sciences* **26**: 1038-1046.

JAYASENA, D.D., JUNG, S., BAE, Y.S., KIM, S.H., LEE, S.K., LEE, J.H. and JO, C. (2014a) Changes in endogenous bioactive compounds of Korean native chicken meat at different ages and during cooking. *Poultry Science* **93**: 1842-1849.

JAYASENA, D.D., KIM, S.H., LEE, H.J., JUNG, S., LEE, J.H., PARK, H.B. and JO, C. (2014b) Comparison of the amounts of taste-related compounds in raw and cooked meats from broilers and Korean native chickens. *Poultry Science* **93**: 3163-3170.

JAYASENA, D.D., JUNG, S., BAE, Y.S., PARK, H.B., LEE, J.H. and JO, C. (2015a) Comparison of the amounts of endogenous bioactive compounds in raw and cooked meats from commercial broilers and indigenous chickens. *Journal of Food Composition and Analysis* **37**: 20-24.

JAYASENA, D.D., JUNG, S., KIM, S.H., KIM, H.J., ALAHAKOON, A.U., LEE, J.H. and JO, C. (2015b) Endogenous functional compounds in Korean native chicken meat are dependent on sex, thermal processing, and the meat cut. *Journal of the Science of Food and Agriculture* **95**: 771-775.

JAYASENA, D.D., JUNG, S., PARK, H.B., LEE, J.H., NAM, K.C., LEE, K.H. and JO, C. (2015c) Taste-active compound levels in Korean native chicken meat: The effects of bird age and the cooking process. *Poultry Science* **94**: 1964-1972.

JEON, H.-J., CHOE, J.-H., JUNG, Y., KRUK, Z.A., LIM, D.-G. and JO, C. (2010) Comparison of the chemical composition, textural characteristics, and sensory properties of North and South Korean native chickens and commercial broilers. *Korean Journal for Food Science of Animal Resources* **30**: 171-178.

JIN, S., SEO, D., SIM, J., BAEK, W., JUNG, K., JANG, B., CHOI, K. and LEE, J. (2009) Single nucleotide polymorphism analysis of the CO□gene in Korean native chicken. *Korean Journal of Poultry Science* **36**: 85-88.

JIN, S., PARK, H., SEO, D., CAHYADI, M., CHOI, N., HEO, K., JO, C. and LEE, J. (2014) Association of mc1r genotypes with shank colour traits in Korean native chicken. *Livestock Science* **170**: 1-7.

JUNG, K.-C., HOQUE, M.R., SEO, D.-W., PARK, B.-K., CHOI, K.-D. and LEE, J.H. (2009) Genotype analysis of the Major Histocompatibility Complex region in Korean native chicken. *Korean Journal of Poultry Science* **36**: 317-322.

JUNG, S., BAE, Y.S., KIM, H.J., JAYASENA, D.D., LEE, J.H., PARK, H.B., HEO, K.N. and JO, C. (2013) Carnosine, anserine, creatine, and inosine 5'-monophosphate contents in breast and thigh meats from five lines of Korean native chicken. *Poultry Science* **92**: 3275-3282.

JUNG, Y., JEON, H.J., JUNG, S., CHOE, J.H., LEE, J.H., HEO, K.N., KANG, B.S., and JO, C. (2011) Comparison of quality traits of thigh meat from Korean native chickens and broilers. *Korean Journal for Food Science of Animal Resources* **31**: 684-692.

KANG, B.S., CHEONG, I.C., LEE, S.J., KIM, S.H., OHH, B.K. and CHOI, K.S. (1997a) Estimation of heterosis for some economic traits in crossbreds between Korean native chicken and Rhode island red I. Hatching and growing performance in crossbreds between Korean native chicken and Rhode Island Red. *Korean Journal of Poultry Science* **24**: 117-126.

KANG, B.S., CHEONG, I.C., LEE, S.J., KIM, S.H., OHH, B.K. and CHOI, K.S. (1997b) Estimation of heterosis for some economic traits in crossbreds between Korean native chicken and Rhode island red II. Laying performance of Korean native chicken and Rhode Island Red crossbreds. *Korean Journal of Poultry Science* **24**: 217-137.

KANG, B.S., LEE, S.J., KIM, S.H., KIM, W.B. and OHH, B.K. (1998a) Study on performance and meat characteristics in Korean native commercial chicken I. Study on performance in Korean native commercial chicken by feeding system. *Korean Journal of Poultry Science* **25**: 129-136.

KANG, B.S., LEE, S.J., KIM, S.H., SUH, O.S., NA, J.C., JANG, B.G., PARK, B.Y., LEE, J.M. and OHH, B.K. (1998b) Study on performance and meat characteristics in Korean native commercial chicken - II. Study on meat characteristics in Korean native commercial chicken by feeding system. *Korean Journal of Poultry Science* **25**: 137-145.

KANG, B.-S., HONG, E.-C., KIM, H.-K., YU, D.-J., PARK, M.-N., SEO, B.-Y., CHOO, H.-J., NA, S.-H., SEO, O.-S. and HWANGBO, J. (2010) Hatching and growing performance of three-way crossbreds of Korean native chickens (KNC). *Korean Journal of Poultry Science* **37**: 399-404.

KLUNGLAND, H. and VÅGE, D. (2003) Pigmentary switches in domestic animal species. *Annals of the New York Academy of Sciences* **994**: 331-338.

KONG, H., OH, J., LEE, J., JO, K., SANG, B., CHOI, C., KIM, S., LEE, S., YEON, S. and JEON, G. (2006) Genetic variation and relationships of Korean native chickens and foreign breeds using 15 microsatellite markers. *Asian-Australasian Journal of Animal Sciences* **19**: 1546-1550.

KWAK, W., SONG, K.D., OH, J.D., HEO, K.N., LEE, J.H., LEE, W.K., YOON, S.H., KIM, H., CHO, S. and LEE, H.K. (2014) Uncovering genomic features and maternal origin of Korean native chicken by whole genome sequencing. *PLoS One* **9**: e114763.

KWEON, Y.J., YEO, J.S. and SUNG, S.K. (1995) Quality characteristics of Korean native chicken meat. *Korean Journal of Poultry Science* **22**: 223-231.

LEE, H.K., CHUNG, H.K., OH, H.K., CHUN, B.S., YOU, C.H., CHUN, K.J., KIM, K.N., LEE, K.W., HAN, J.Y. and CHUNG, E.R. (1996a) Analysis of genetic characteristics by biochemical genetic markers in Korean native chicken. *Korean Journal of Poultry Science* **23**: 135-144.

LEE, H.K., LEE, S.J., HWANG, K.C., CHEONG, I.C., PARK, Y.H., SHON, S.H., SHIN, Y.S., OHH, B. K. and HAN, J.Y. (1996b) Analysis of genetic characteristics of Korean native chicken using DNA marker. *Korean Journal of Poultry Science* **23**: 177-183.

LEE, K.-H., JUNG, Y., JUNG, S., LEE, J.H., HEO, K.N. and JO, C. (2011) Physiochemical characteristics of the meat from Korean native chicken and broiler reared and slaughtered as the same conditions. *Korean Journal of Poultry Science* **38**: 225-230.

LEE, M.-J., KIM, S.-H., HEO, K.-N., KIM, H.-K., CHOI, H.-C., HONG, E.-C., CHOO, H.-J. and KIM, C.-D. (2013) The study on productivity of commercial Korea chickens for crossbred Korean native chickens. *Korean Journal of Poultry Science* **40**: 291-297.

LEE, M.-J., HEO, K.-N., CHOI, H.-C., HONG, E.-C. and KIM, C.-D. (2014) The performance test in crossbreds of Korean native chickens for the establishment of new lines. *Korean Journal of Poultry Science* **41**: 39-44.

LEE, Y. (2006) Taiwan country chicken: A slow growth breed for eating quality. Proceedings of 2006 Symposium COA/INRA Scientific Cooperation in Agriculture, Tainan, pp. 121-132.

LIN, J.Y. and FISHER, D.E. (2007) Melanocyte biology and skin pigmentation. *Nature* **445**: 843-850.

LIU, Y.-P., WU, G.-S., YAO, Y.-G., MIAO, Y.-W., LUIKART, G., BAIG, M., BEJA-PEREIRA, A., DING, Z.-L., PALANICHAMY, M. G. and ZHANG, Y.-P. (2006) Multiple maternal origins of chickens: Out of the Asian jungles. *Molecular Phylogenetics and Evolution* **38**: 12-19.

MEUSNIER, I., SINGER, G.A., LANDRY, J.-F., HICKEY, D.A., HEBERT, P.D. and HAJIBABAEI, M. (2008) A universal DNA mini-barcode for biodiversity analysis. *BMC genomics* **9**: 1.

MIAO, Y., PENG, M., WU, G., OUYANG, Y., YANG, Z., YU, N., LIANG, J., PIANCHOU, G., BEJA-PEREIRA, A. and MITRA, B. (2013) Chicken domestication: An updated perspective based on mitochondrial genomes. *Heredity* **110**: 277-282.

NIU, D., FU, Y., LUO, J., RUAN, H., YU, X.-P., CHEN, G. and ZHANG, Y.-P. (2002) The origin and genetic diversity of Chinese native chicken breeds. *Biochemical Genetics* **40**: 163-174.

PARK, M.-N., HONG, E.-C., KANG, B.-S., KIM, H.-K., SEO, B.-Y., CHOO, H.-J., NA, S.-H., SEO, O.-S., HAN, J.-Y. and HWANGBO, J. (2010) The study on production and performance of crossbred Korean native chickens (KNC). *Korean Journal of Poultry Science* **37**: 347-354.

PARK, M.-N., HONG, E.-C., KANG, B.-S., HWANGBO, J. and KIM, H.-K. (2011) Performance and meat quality of three-crossbreed Korean native chickens (KNC). *Korean Journal of Poultry Science* **38**: 293-304.

PARK, M.N., CHOI, J.A., LEE, K.T., LEE, H.J., CHOI, B.H., KIM, H., KIM, T.H., CHO, S. and LEE, T. (2013) Genome-wide association study of chicken plumage pigmentation. *Asian-Australasian Journal of Animal Sciences* **26**: 1523-1528.

RUBIN, C.-J., ZODY, M.C., ERIKSSON, J., MEADOWS, J.R., SHERWOOD, E., WEBSTER, M.T., JIANG, L., INGMAN, M., SHARPE, T. and KA, S. (2010) Whole-genome resequencing reveals loci under selection during chicken domestication. *Nature* **464**: 587-591.

SANG, B.D., KONG, H.S., KIM, H.K., CHOI, C.H., KIM, S.D., CHO, Y.M., SANG, B.C., LEE, J.H., JEON, G.J. and LEE, H.K. (2006) Estimation of genetic parameters for economic traits in Korean native chickens. *Asian-Australasian Journal of Animal Sciences* **19**: 319-323.

SEO, D.W., HOQUE, M.R., CHOI, N.R., SULTANA, H., PARK, H.B., HEO, K.N., KANG, B.S., LIM, H. T., LEE, S.H., JO, C. and LEE, J.H. (2013) Discrimination of Korean native chicken lines using fifteen selected microsatellite markers. *Asian-Australasian Journal of Animal Sciences* **26**: 316-322.

SEO, D.W., OH, J.D., JIN, S., SONG, K.D., PARK, H.B., HEO, K.N., SHIN, Y., JUNG, M., PARK, J., JO, C., LEE, H.K. and LEE, J.H. (2014) Single nucleotide polymorphism analysis of Korean native chickens using next generation sequencing data. *Molecular Biology Reports* **42**: 471-477.

SEO, J.H., OH, J.-D., LEE, J.-H., SEO, D. and KONG, H.S. (2015a) Studies on genetic diversity and phylogenetic relationships of Korean native chicken using the microsatellite marker. *Korean Journal of Poultry Science* **42**: 15-26.

SEO, D.W., PARK, H.B., CHOI, N.R., JIN, S., YOO, C.K., SULTANA, H., HEO, K.N., JO, C. and LEE, J.H. (2015b) Construction of genetic linkage map using microsatellite and SNP markers in Korean native chicken. *Korean Journal of Poultry Science* **42**: 77-86.

SEO, D., PARK, H., JUNG, S., CAHYADI, M., CHOI, N., JIN, S., HEO, K., JO, C. and LEE, J. (2015c) QTL analyses of general compound, colour, and pH traits in breast and thigh muscles in Korean native chicken. *Livestock Science* **182**: 145-150.

SOHN, S.-H., PARK, D.-B., SONG, H.-R., CHO, E.-J., KANG, B.-S. and SUH, O.-S. (2012) Genotype frequencies of the sex-linked feathering and their phenotypes in domestic chicken breeds for the establishment of auto-sexing strains. *Journal of Animal Science and Technology* **54**: 267-274.

SOHN, S.H., KIM, N.Y., PARK, D.B., SONG, H.R., CHO, E.J., CHOI, S.B., HEO, K.N. and CHOI, H.C. (2013) Influence of early- and late-feathering phenotype on productive performance in the feather-sexing strains of Korean native chicken. *Korean Journal of Poultry Science* **40**: 263-270.

SUH, S., SHARMA, A., LEE, S., CHO, C.Y., KIM, J.H., CHOI, S.B., KIM, H., SEONG, H.H., YEON, S. H., KIM, D.H. and KO, Y.G. (2014) Genetic diversity and relationships of Korean chicken breeds based on 30 microsatellite markers. *Asian-Australasian Journal of Animal Sciences* **27**: 1399-1405.

SULTANA, H., HOQUE, M.R., SEO, D.-W., KANG, B.-S., HEO, K.-N., JO, C. and LEE, J.-H. (2012) Mitochondrial D-loop variations for discrimination of commercial Korean native chicken populations. *Korean Journal of Poultry Science* **39**: 311-315.

TANG, H., GONG, Y., WU, C., JIANG, J., WANG, Y. and LI, K. (2009) Variation of meat quality traits among five genotypes of chicken. *Poultry science* **88**: 2212-2218.

YEO, J.S. (1992) Study of the genetic characteristics in the Korean native chicken. *Journal of Resource Development* **11**: 23-27.

YUKIO, A. (2005) Preservation and utilisation of native chickens in Japan. Proceedings of 2005 International Symposium on native chicken, Korea International Livestock Expo, Daejeon, pp. 35-43.

Table 1 General composition, physicochemical traits, and taste-active and bioactive compound contents of breast and thigh/leg meat from Korean native chickens and commercial broilers.

Quality trait	Breast meat		Thigh/Leg meat[a]		Reference
	Korean native chicken	Commercial broiler	Korean native chicken	Commercial broiler	
Crude protein (%)	21.63-24.63	21.34-23.97	17.63-20.59	16.90-19.45	Choe *et al.* (2010), Jung *et al.* (2011), Jeon *et al.* (2010), Lee *et al.* (2011), Jayasena *et al.* (2013), Kweon *et al.* (1995)
Crude fat (%)	1.02-2.53	1.48-2.27	2.11-3.63	3.11-6.18	
Total collagen (mg/g)	1.09-4.00	0.65-5.73	2.97-6.78	2.03-7.92	
pH	5.54-5.92	5.90-6.21	6.14-6.55	6.50-6.77	
L*	54.00-64.00	48.67-56.82	44.95-48.90	48.92-51.62	Choe *et al.* (2010), Jung *et al.* (2011), Jeon *et al.* (2010), Lee *et al.* (2011), Jayasena *et al.* (2013)
a*	1.63-8.30	6.39-7.78	7.70-14.87	8.73-9.91	
b*	14.30-18.44	18.88-21.72	11.61-18.98	16.88-18.87	
Taste-active compounds					
Inosine 5'-monophosphate (mg/100 g)	197.24-446.30	153.90-213.27	54.21-231.56	42.92-154.80	Choe *et al.* (2010), Jung *et al.* (2011), Jayasena *et al.* (2013), Jung *et al.* (2013)
			125.68-224.10*	70.20*	Jayasena *et al.* (2014b), (2015c)
Glutamic acid (mg/100 g)	18.09-28.51	16.57-18.80	29.21	21.99	Ahn and Park (2002)
			30.80-31.83*	21.10*	Jayasena *et al.* (2014b), (2015c)
Cysteine (mg/100 g)	3.25-4.10	4.10	2.30-2.87*	2.40*	Jayasena *et al.* (2014b), (2015c)
Reducing sugar (%)	0.11-0.13	0.05	0.14-0.16*	0.10*	
Oleic acid (%)	21.59-32.16	28.72-38.72	23.18-43.15	27.79-45.50	Choe *et al.* (2010), Jung *et al.* (2011), Jeon *et al.* (2010), Jayasena *et al.* (2013)
			22.88-25.70*	38.70*	Jayasena *et al.* (2014b), (2015c)
Linoleic acid (%)	13.92-20.26	12.82-16.80	16.74-18.71	14.62-19.41	Choe *et al.* (2010), Jung *et al.* (2011), Jeon *et al.* (2010), Jayasena *et al.* (2013)
			25.30-27.26*	18.10*	Jayasena *et al.* (2014b), (2015c)
Arachidonic acid (%)	4.26-14.34	2.70-3.40	2.72-7.54	1.11-5.74	Choe *et al.* (2010), Jung *et al.* (2011), Jeon *et al.* (2010), Jayasena *et al.* (2013)
			7.30-8.86*	1.80*	Jayasena *et al.* (2014b), (2015c)
EPA (%)[b]	0.36	0.11	0.28-0.58	0.13-0.72	Jung *et al.* (2011), Jayasena *et al.* (2013)
DHA (%)[c]	1.89-4.90	0.47-0.53	0.58-1.53	0.12-1.65	Jung *et al.* (2011), Jeon *et al.* (2010), Jayasena *et al.* (2013)
			2.60-3.31*	0.20*	Jayasena *et al.* (2014b), (2015c)

Table 1 Continued

Quality trait	Breast meat		Thigh/Leg meat[a]		Reference
	Korean native chicken	Commercial broiler	Korean native chicken	Commercial broiler	
Bioactive compounds (mg/100 g)					
Carnosine	148.00-182.00	138.00	85.60	66.20	Jung *et al.* (2013)
			68.00-76.80*		Jayasena *et al.* (2014a), (2015a), (2015b)
Anserine	524.00-849.60	482.00	346.50	167.00	Jung *et al.* (2013)
			207.60-273.00*		Jayasena *et al.* (2014a), (2015a), (2015b)
Betaine	3.84-6.31	11.90	11.00-15.20*	20.8	Jayasena *et al.* (2014a), (2015a), (2015b)
Carnitine	5.18-7.16	5.76	10.00-13.10*	4.72	
Creatine	299.00-407.20		408.20		Jung *et al.* (2013)
			306.00-372.00*		Jayasena *et al.* (2014a), (2015b)

[a] Values with the mark (*) represents those from leg meat; [b]Eicosapentaenoic acid; [c]Docosahexaenoic acid