THE PRESENT AND FUTURE OF BEEF PRODUCTION IN SOUTH KOREA

Dilla Mareistia Fassah, DaJinSol Jung, and Myunggi Baik
Department of Agricultural Biotechnology, College of Agriculture and Life Sciences, Seoul National University, Seoul 08826, Republic of Korea
e-mail: mgbaik@snu.ac.kr

In South Korea, the livestock industry, including the beef industry, is very important for several reasons: 1) it is the main source of income for farmers; 2) it contributes to public health by providing good sources of energy and protein; 3) it contributes to food security; 4) it plays an important role in environmental preservation; and 5) it enhances quality of life for South Koreans (companionship, recreation, recycling of animal waste, etc.). The livestock industry’s output has recently increased, and in 2015 it accounted for 41% (19.1 trillion Korean won) of total agricultural output (46.6 trillion won) [Korea Rural Economic Institute (KREI), 2017]. Until 2015, rice was the most economically important of all agricultural and livestock outputs. However, in 2016 the pork industry (6.8 trillion won) became the most important output; rice (6.5 trillion won) was second, and beef (4.7 trillion won) third.

The livestock industry is expected to grow further, and account for 45% of total agriculture output by 2020 (KREI, 2017). Consumption of livestock products has also increased. The total consumption of meat, milk, and eggs per year was 19.9kg, 42.8kg, and 167 ea. in 1990, and 49.5kg, 75.5kg, and 268 ea. in 2016, respectively. Beef consumption was 10.2 kg per capita in 2011, 11.5 kg in 2016, and is expected to increase to 13.2 kg in 2026. The total amount of beef consumption was 519 thousand tons (retail cuts) in 2013, and 581 thousand tons in 2016. The self-sufficiency rate of beef was 50% in 2013 and 37.7% in 2016. The primary importers of beef in 2016 were Australia (49%) and USA (42%). The scale of the livestock industry has also increased. Beef cattle farm households numbered about 290,000 in 2000, but decreased to 91,000 in 2016. The number of cattle per farm was 5.5 in 2000, but increased to 30.4 in 2016. While there were only 1.4 million beef cattle in 2001, there were 2.7 million in 2016.

Beef is graded for both quality grade (QG) and yield grade (YG) using the Korean Beef Carcass Grading System. There are five QGs [QG1++ (best), QG1+, QG1, QG2, and QG3 (worst)] and three YGs [A (highest), B, C (lowest)]. The main factors affecting QG are marbling score (MS) and intramuscular fat (IMF) content, although meat color, fat color and maturity also have minor effects. MS is scored on a 9-point scale, from 1 (devoid) to 9 (abundant). Japanese Wagyu longissimus dorsi muscle (LM) contains the highest levels of IMF in the world, and Korean cattle beef contains the second highest IMF when cattle are raised under conventional fattening programs. The quality grade of Korean cattle steer beef has gradually improved, and currently 80% of QG scores are above QG1. However, YG has decreased: the rate of YG A scores was 36% in 2000, but only 26% in 2015. The livestock industry is expected to become more important in the future. The Korean government has clear visions for the livestock industry, including reducing odor and manure/waste, developing sustainable agriculture and establishing smart farming and animal welfare systems.
INTRODUCTION

The livestock industry, including beef production, is critically important in South Korea for several reasons. For example, it represents a major source of income for farmers, provides a significant contribution to public health, and helps to preserve the environment. The livestock industry is expected to become the most important agricultural sector, given that the proportion of South Korea’s total agricultural output accounted for by the livestock industry has increased in recent years. Global meat consumption has the highest rate of growth out of all agricultural commodities. In Korea, a significant increase in income has led to increased standards of living, and consumers’ diet patterns have shifted from rice to meat, including beef.

The quality traits and nutritional composition of beef from Korean cattle (also called Hanwoo) are different from other cattle breeds. Hanwoo beef is characterized by high levels of marbled fat and a specific flavor. Hanwoo beef have the second highest levels of intramuscular fat (IMF) in the longissimus dorsi muscle (LM), and the price of Hanwoo beef is the second highest in the world. (Japanese Wagyu beef has the highest IMF content and is the most expensive in the world.) Hanwoo beef is evaluated by quality grade (QG) and yield grade (YG) based on the Korean Beef Carcass Grading System. The QG is determined mainly by IMF content. In Korea, most Hanwoo bulls are castrated to increase IMF and QG; however, this practice negatively affects YG. The Korean Hanwoo industry has faced several challenges, including high production costs, diseases, environmental and animal welfare issues, and competition with imported beef. However, production trends and the increasing demand for beef provide opportunities for expanding the beef cattle industry in Korea.

In this paper, we summarize the latest information for the livestock and beef cattle industries in Korea, and discuss future trends. We also review the Korean Beef Carcass Grading System and describe ongoing research conducted at the Ruminant Nutrition and Physiology Laboratory at Seoul National University.

THE LIVESTOCK INDUSTRY IN SOUTH KOREA

The livestock industry is the most important agricultural sector in South Korea. In 2000, the output of the livestock industry was 8.1 trillion won. The livestock industry’s output has recently increased, and in 2015 it accounted for 41% (19.1 trillion Korean won) of total agricultural output (46.6 trillion won), becoming the most important source of income for farmers (Korea Rural Economic Institute (KREI), 2017) (Fig. 1). Until 2015, rice was the most economically important of all agricultural and livestock outputs. However, in 2016 the pork industry (6.8 trillion won) became the most important output; rice (6.5 trillion won) was second, and beef (4.7 trillion won) third. The livestock industry is expected to grow further, and account for 45% of total agriculture output by 2020 (KREI, 2017).

As the national income in South Korea has increased, so too has the consumption of livestock products. The
per capita consumption of meat, milk, and eggs has increased 1.4–2.2-fold over the past 20 years. Total annual meat, milk, and egg consumption was 19.9kg, 42.8kg, and 167 ea. in 1990, and 49.5kg, 75.5kg, and 268 ea. in 2016, respectively (Table 1). Among Asian countries, Korea, along with Japan and China, have the highest rates of meat consumption. Korean pork consumption is similar to that of the USA; however, beef and chicken consumption are still lower than those of the USA.

The livestock industry has also increased in scale. Owing to specialization [specialized farm household = households that raise more than 50 Hanwoo and dairy cows/1,000 pigs/30,000 chickens], the number of cattle-farming households has decreased, but individual farm size has increased. Beef cattle-farming households numbered about 290,000 in 2000, but only 91,000 in 2016. The number of cattle per farm was 5.5 in 2000, but increased to 30.4 in 2016.

**THE PRESENT BEEF CATTLE INDUSTRY IN SOUTH KOREA**

The number of beef cattle has varied among years: there were 1.4 million in 2001, 3.0 million in 2012, and 2.7 million in 2016. Beef consumption has increased, and is expected to continue increasing steadily: 10.2 kg/per capita in 2011, 11.5 kg in 2016, 12.2kg in 2021, and 13.2 kg in 2026. Total beef consumption was 519 thousand tons (retail cuts) in 2013 and 581 thousand tons in 2016. The self-sufficiency rate of beef was 50.1% in 2013, but has decreased and is expected to continue decreasing: 37.7% in 2016 and 36.7% in 2026 (Fig. 2). The main importers of Korean beef in 2016 were Australia (49%) and USA (42%).

Hanwoo beef is popular in South Korea for its high level of marbling. The combination of highly marbled meat, tenderness, juiciness and unique flavor create the characteristic taste of Hanwoo beef. However, compared to other beef cattle breeds, Hanwoo have lower carcass weights. Therefore, many studies have been conducted on increasing both the quality (marbling, tenderness and flavor) and quantity (carcass weight) of Hanwoo. Genetic improvements have increased the live weight of Hanwoo bulls at 18 months of age from 305.7 kg (1977) to 552.8 kg (2014).

Korea has its own carcass grading system, which was established in 1992. There are two main parameters for evaluating beef carcass quality: YG and QG. The combination of YG and QG is used to determine beef quality grade (Table 2). Yield grade is divided into three classes: A (highest), B, and C (lowest). Yield grade is determined based on several factors, including rib-eye area, back fat thickness and carcass weight. QG is divided into five classes: 1++ (best), 1+, 1, 2, 3 (worst) (KAPE, 2013). The main criteria for QG are marbling score (MS) and intramuscular fat (IMF) content, although meat color, fat color, and maturity also have minor effects. MS is scored on a 9-point scale, from 1 (devoid) to 9 (abundant) (Fig. 3). QG1++ is considered to be the premium class of beef in Korea, and should a MS of 8 or 9, whereas QG3 has a MS of 1. The quality grade of Korean cattle beef has improved: currently, over 80% of steers scores for above QG1 (Fig. 4). However, yield grade has gradually decreased: the highest historical rate of YG A scores was 36.2%, in 2000, but only 26.1% in 2015. Meanwhile, the lowest historical rate of YG C scores was 10.7%, in 2000, but 22.7% in 2015 (Fig. 5).

In Korea, the production of highly marbled beef is essential in order to compete with cheap imported beef that has relatively low MS. Japanese Wagyu LM contains the highest levels of IMF (26.3%; Matsuhashi et al. 2011), and
Korean cattle beef contains the second highest levels of IMF (13.3%; Jeong et al. 2012), when cattle are raised under conventional fattening programs. In Korea, differences in QG largely determine beef price. For example, in 2012 the price of QG 1++ beef was 17,269 won/kg (14.8$/kg), whereas the price of QG 3 beef was 8,082 won/kg (7.0$/kg). This price difference is over 3 million won/600 kg (live weight) of beef cattle. Hanwoo beef is normally the second most expensive beef in the world, while Japanese Wagyu beef is the most expensive. Korean consumers generally are willing to purchase Hanwoo beef because of its excellent taste and quality. Our unpublished data show that Hanwoo beef had superior overall sensory properties, including flavor, tenderness, and overall acceptance, as compared to domestic Holstein and imported Angus beef. Castration is the most effective means of increasing MS. The castration rate of bulls has increased, from about 60% in 2004 to over 90% in 2015 (Fig. 4).

THE FUTURE OF THE LIVESTOCK AND BEEF CATTLE INDUSTRY IN SOUTH KOREA

The livestock industry, including the beef cattle industry, is expected to become more important both in Korea and globally. The world has faced four major problems in the 21st century, including food, public health, the environment, and energy. The livestock industry has been suggested as a potential solution to all of these problems. The livestock industry not only serves as a source of animal protein but also may contribute to public health issues through the development of alternative organs (e.g. cloned pigs) and bioreactors for the production of useful proteins from transgenic animals. This industry helps protect ecological environments. Moreover, manure from the livestock industry can be converted into biogas to generate energy.

In 2014, the South Korea Ministry of Agriculture introduced a government plan for developing a sustainable, eco-friendly livestock industry in South Korea. The main aims of this program are reducing odor and manure/waste, developing sustainable agriculture, and establishing animal welfare programs. The goals of the program are 1) to develop a sustainable, eco-friendly livestock industry to meet the demands of the Free Trade Agreement (FTA) market, consumer needs and environmental standards; 2) to increase manure recycling and biogas production (from 9% in 2012 to 17% in 2022); and 3) to increase the percentage of certified eco-friendly livestock products (from 0.7% in 2012 to 10% in 2022). To achieve these goals, five strategies have been employed, including strengthening production systems, establishing the distribution and consumer market, ensuring a stable supply of feed and equipment, increasing certified eco-friendly livestock products, and minimizing environmental burden.

The future of the livestock industry in South Korea includes 1) establishing a sixth industry, the agriculture & food field; 2) applying nano, cultural and informational (NCI) technologies to the agriculture & food industry; 3) developing functional food; and 4) developing the livestock biotechnology industry. The Korean government promotes the establishment of a sixth industry, which is of fusion of the livestock, tourism, culture, technology, restaurant and distribution industries. NCI technologies have been applied to the agriculture and food industry to develop smart farming practices. The application of NCI technologies to farming systems will simplify the management of livestock data and information, as well as environmental control. The livestock industry also plays a role in the development of functional food, since its products contribute to a healthy diet. The main business areas of functional food in the livestock industry include the production of conjugated linoleic acid (CLA) and L-carnitine-
intensified dairy, meat, or egg products; the development of feed additives to increase biologically active substances in livestock products, and verification of the effects of functional food. Biotechnology could one day become the core business of the livestock industry. Animal biotechnology encompasses a broad range of techniques, such as animal cloning, the creation of transgenic animals, and the use of laboratory animals and insects.

In recent years, the beef cattle industry in Korea has faced several challenges. Livestock feed cost has increased owing to increases in both biofuel production and world grain prices. Public concerns about animal diseases have also increased (bovine spongiform encephalopathy, foot and mouth disease, etc.), as well awareness of environmental issues (methane, animal waste, odor, etc.) and animal welfare. The globalization of the meat market has increased beef imports, leading to a decrease in the size of the beef cattle industry in Korea. All of these issues ultimately increase the cost of beef production and decrease farmers’ incomes. However, the Korean beef cattle industry also has many opportunities for expansion. Consumption of meat, including beef, has increased, and is expected to continue increasing. The World Bank estimates that the world population will grow to 9 billion by 2050. The United Nations estimates that world meat consumption will increase by about 53%, by 2050. Similarly, world milk consumption is estimated to increase by 75%, by 2050. These factors should provide a stimulus for the expansion of the beef cattle industry, both in Korea and in other countries. The KREI (2012) estimates that the cost of importing meat to China will reach 150 billion dollars by 2050. In Korea, the export of high-marbled beef to other countries is at an early stage. The amount of exported highly marbled Hanwoo beef to Hong Kong in 2016 (Jan to Oct) was 1,035 tons, worth 7 million dollars. The future directions of the Korean beef cattle industry include 1) maintaining high-quality beef production systems (e.g. modifying the beef grading system, exporting high-quality beef); 2) increasing production efficiency (e.g. increasing growth rate and feed efficiency, reducing age at slaughter); 3) applying ICT fusion technology and smart farming systems; 4) increasing sustainable, environmentally friendly systems (mitigation of waste, methane production and antibiotic usage); and 5) mitigating stress and increasing animal welfare.

**BEEF CATTLE RESEARCH AT SEOUL NATIONAL UNIVERSITY**

Beef cattle research at Seoul National University (SNU) has been carried out mainly at the SNU Animal Farm, which was built in Pyeongchang in 2013. Many factors are involved in IMF deposition in beef, including genetic, management-related and nutritional factors. Currently, the laboratory of Ruminant Nutrition and Physiology at SNU is conducting beef cattle research in several areas, including elucidation of the molecular mechanisms of IMF deposition, nutrigenomic studies, improvement of fatty acid (FA) composition in beef, and stress mitigation and welfare in ruminants. Several functional genomics tools, including transcriptomics (real-time PCR, microarray, RNA sequencing), proteomics and epigenomics (DNA methylation), have been applied to study the molecular mechanisms of IMF deposition in Korean cattle (reviewed in Baik et al. 2017). We have found that integration of the endocrinial and peripheral signals following castration influences IMF deposition (Bong et al., 2012; Jeong et al. 2013a) by altering the lipid metabolism in the LM (Jeong et al. 2012), liver (Baik et al. 2015) and adipose tissue (Jeong et al. 2013b; Baik et al. 2014). Our studies demonstrate that lipid metabolism in the LM is important for
regulation of IMF deposition, whereas hepatic lipid metabolism has only minor effects on IMF deposition. We also found that the combined effects of increases in FA uptake, de novo FA synthesis, FA esterification and triglycerol synthesis, as well as decreased lipolysis, contribute to increased IMF content in the LM following castration.

Nutrigenomics is the application of high-throughput genomic tools to nutrition research (Müller and Kersten 2003). Nutrigenomics may be able to aid the development of precise feeding routines for specific phenotypes (e.g., beef quality-specific, fast growing, and heat stress-resistant individual), thus maximizing the expression of economic traits. We have recently employed nutrigenomics to develop genome-based precision feeding to maximize animal production efficiency. First, we breeds Hanwoo into two groups (a high-quality beef production group and a fast-growing group based on breeding values and DNA chip data). After individual animals are separated into these two groups, customized feeding programs for either high QG or fast growth can be applied.

One other ongoing research area focuses on improving FA composition in beef. FAs have different characteristics that influence beef quality and human health. Saturated FAs are known to have adverse effects on human health. For example, stearic acid is known to promote cardiovascular disease (Daley et al., 2010). Poly-unsaturated FAs, such as eicosapentanoic acid (EPA) and docosahexanoic acid (DHA), benefit human health by helping to prevent atherosclerosis and heart attack (Nassu et al. 2011; Scollan et al., 2006). Mono-unsaturated FAs, such as oleic acid, are known to enhance flavor and tenderness (Ohsaki et al. 2009). Conjugated linoleic acid is known to have several beneficial effects on human health, such as inhibition of cancer and diabetes (Nassu et al. 2011). Therefore, strategies are needed to increase the concentration of beneficial FAs. FA composition in beef is influenced by three main factors: rumen microbes, genetics, and diet (Table 3). Unsaturated FA is prone to hydrogenation by rumen microbes. This generates not only more saturated FA but also conjugated linoleic acid, while reducing unsaturated FA (Jenkins, 1993). Stearoyl CoA desaturase is a specific enzyme involved in FA desaturation. Increased expression of desaturase genes is associated with higher unsaturated FA content (Mannen 2011). Several dietary supplements may increase beneficial FA content in beef. Compared with grains, forage diets contain more linoleic and linoleic acids, which are expected to produce more oleic acid, DHA and CLA (Scollan et al. 2006). Linseed contains 50–60% alpha-linoleic acid, and addition of linseed improves the contents of EPA, DHA and CLA in beef (Nassu et al. 2011; Xu et al. 2008). Palm oil is rich in oleic acid, and its addition in feed improves the oleic acid content and flavor of beef (Partida et al. 2007).

CONCLUSION

The livestock industry, including the beef industry, is important for the economy, the environment, and public health in South Korea. The beef cattle industry in Korea faces several challenges, including the high cost of beef production, public concerns over animal diseases and welfare, and decreases in the self-sufficiency rate owing to globalization. However, the global consumption of meat (including beef) is expected to increase by over 50%, by 2050, owing to population growth. Accordingly, the beef cattle industry should become more important in the future. The Korean government has clear goals for the livestock industry, including increased production efficiency, reduced odor and manure/waste, development of sustainable agriculture, application of new technologies,
establishment of animal welfare systems, and export of high-quality meat. Hanwoo beef is known to have several important attributes (high IMF content, good flavor, and hygiene/safety). Increasing beneficial FA content will increase the value of Hanwoo beef. The fusion of ICT technologies and smart/environmentally friendly farming systems may promote the production of high-quality beef and decrease costs. These strategies will ultimately contribute to better public health and the protection of national sovereignty.

REFERENCES


### Table 1. Consumption of livestock products in Korea

<table>
<thead>
<tr>
<th>Category</th>
<th>1990 (A)</th>
<th>2000</th>
<th>2010</th>
<th>2016 (B)</th>
<th>B/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td>19.9</td>
<td>31.9</td>
<td>38.8</td>
<td>49.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Milk</td>
<td>42.8</td>
<td>59.2</td>
<td>64.9</td>
<td>75.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Egg</td>
<td>167</td>
<td>184</td>
<td>236</td>
<td>268</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture, Food and Rural Affairs of Korea

### Table 2. Korean beef carcass grading system

<table>
<thead>
<tr>
<th>Item</th>
<th>Quality Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1++</td>
</tr>
<tr>
<td>A</td>
<td>1++A</td>
</tr>
<tr>
<td>Yield grade</td>
<td>B</td>
</tr>
<tr>
<td>C</td>
<td>1++C</td>
</tr>
</tbody>
</table>

Source: Korea Institute for Animal Products Quality Evaluation (2013)

### Table 3. Factors affecting fatty acid composition in beef

<table>
<thead>
<tr>
<th>Factors</th>
<th>Characteristics</th>
<th>Outcome</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rumen microbes</td>
<td>Hydrogenation of USFA</td>
<td>Generation of SFA, CLA</td>
<td>Jenkins (1993)</td>
</tr>
<tr>
<td>Genetic factor</td>
<td>Stearoyl-CoA desaturase</td>
<td>↑UFA</td>
<td>Mannen (2011)</td>
</tr>
<tr>
<td>Diets</td>
<td>Forage vs. grains</td>
<td>↑OA, DHA, CLA</td>
<td>Scollan <em>et al.</em> (2006)</td>
</tr>
<tr>
<td></td>
<td>Linseed</td>
<td>↑EPA, DHA, CLA</td>
<td>Nassu <em>et al.</em> (2011)</td>
</tr>
<tr>
<td></td>
<td>Protected fish oil</td>
<td>↑EPA, DHA, CLA</td>
<td>Xu <em>et al.</em> (2008)</td>
</tr>
<tr>
<td></td>
<td>Palm oil</td>
<td>↑OA, flavor</td>
<td>Partida <em>et al.</em> (2007)</td>
</tr>
</tbody>
</table>

SFA: saturated fatty acid, CLA: conjugated linoleic acid, UFA: unsaturated fatty acid, OA: oleic acid, DHA: docosahexaenoic acid, EPA: eicosapentaenoic acid.
Fig. 1. Livestock industry output in South Korea from 1990 – 2015 (KREI, 2017).

Fig. 2. Total beef consumption and self-sufficiency rate of beef in South Korea.
Fig. 3. Beef marbling score (BMS) standard and quality grade (QG) used in South Korea carcass grading system (KAPE, 2013). The QG is divided into five classes: 1++ (best), 1+, 1, 2, 3 (worst). QG 1++ = BMS 8 or 9, QG 1+ = BMS 6 or 7, QG 1 = BMS 4 or 5, QG 2 = BMS 2 or 3, QG 3 = BMS 1.

Fig. 4. Quality grade (QG) and castration rate in Korean cattle from 2004 to 2015.
Fig. 5. Yield grade (YG) distribution of Korean cattle steers from 1998 to 2015. Yield grade is divided into three classes: A (highest), B, and C (lowest).