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Review

Technological demands of meat processing–An Asian perspective

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ABSTRACT

A rapid increase in the economy, population, industrialization, and urbanization of Asian countries has driven the fast development of their meat industries over recent decades. This consistent increase in meat production and consumption in Asia has been the major cause for the development of the global meat industry. Meat production methods and consumption are very diverse across different regions and countries in Asia, and thus, it is impossible to cover the technological demands of all Asian countries in this review. Here, we have mainly highlighted the differences in meat production methods and consumption in Asia during recent decades and the meat technology demands of three east Asian countries, namely China, Korea, and Japan, and one south Asian country, India. A brief introduction of the meat industry, in particular the production and consumption trend in these countries, is provided in this article. The technology demands for fresh and processed meat products are then reviewed.

1. Introduction

Asia is the largest continent in the world with more than 60% of the world population. Depending on the geographic location, Asia is generally divided into eastern Asia, south-eastern Asia, southern Asia, western Asia, central Asia, and northern Asia. Large differences in culture exist across the different Asian areas and countries due to differences in religion, history, economy, and the environment. Thus, the culture of meat consumption and the extent of meat industry development across Asian countries differ markedly as reviewed by Nam, Jo, and Lee (2010).

In the past three decades, the total meat production in Asian countries has been mainly increased because of the rapid growth of the economy and population (Fig. 1). From 1985 to 2014, the meat production increased by 252.47%, from 38.5 to 135.7 Mt. Although the rate of increase has declined in the past 10 years, the total amount of meat production is still gradually increasing (Fig. 1). In the last 10 years, the amount of pork, beef, mutton, chicken, duck, and goose increased by 30.95%, 27.25%, 18.92%, 52.73%, 33.21%, and 27.18%, respectively. Pork remains the major species for production and consumption in Asia, which accounted for 49.05% of the total meat production in 2014. One fourth of the meat produced in Asia in that year was poultry, while beef and mutton accounted for 13.11% and 6.20% of the total meat, respectively. Duck and goose meat made up only 2.63% and 1.83% of the total meat production, respectively. However, most of the global duck and goose meat are produced and consumed in Asian countries, including China, Vietnam, Thailand, Indonesia, and India. Of this, about 70% of the total global production of duck meat is produced and consumed in China, where processed products such as roasted duck, salted duck, press salted duck, and processed duck and duck neck with soy sauce are very popular.

Although the total meat production has been increasing rapidly in the past decades, the average per capita meat consumption in Asia is still low compared to those in Europe and the USA (Fig. 2). This can be partly explained by the fact that grains and vegetables play important roles in consumer's diet in many Asian countries (Nam et al., 2010). The low meat consumption can be also due to the cost, ethics, and religion. In 2014, the per capita meat consumption was 71.31%, 38.79%, and 23.42% in the world, Europe, and the USA, respectively. The average per capita consumption of pork and mutton in Asia was similar to the

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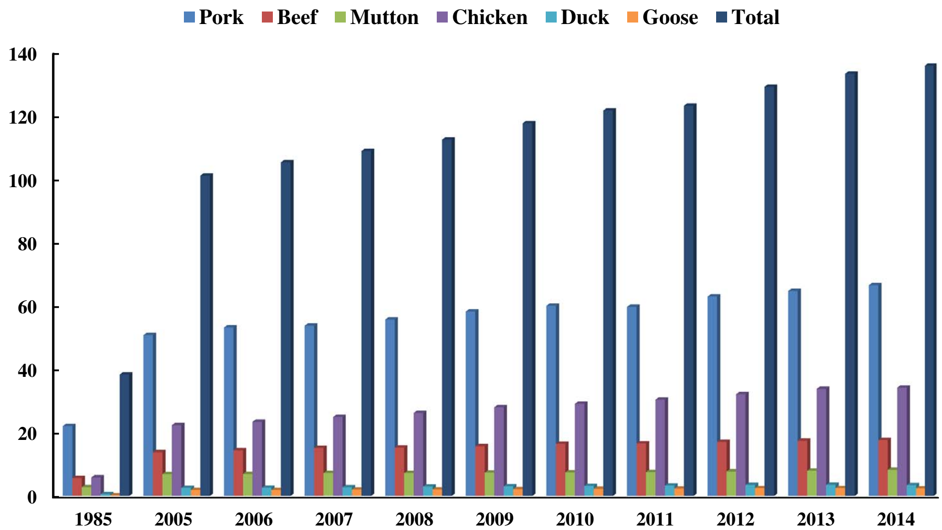

Fig. 1. Meat production in Asia (Mt.).

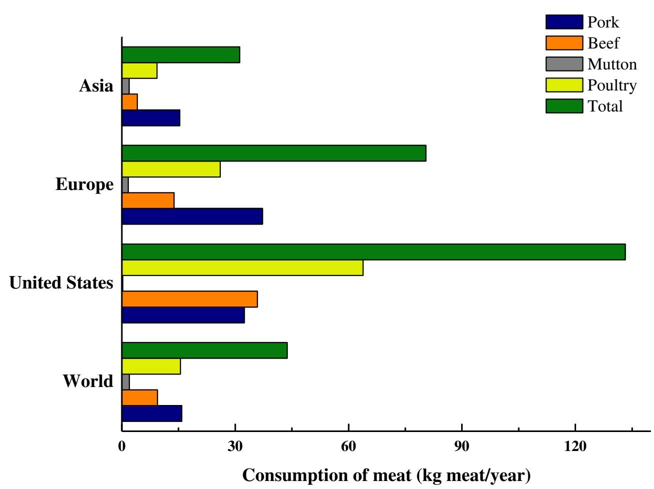

Fig. 2. Per capita consumption of meat (kg meat/year).

world average. Pork remains popular in Asian countries, where the ratios of pork to poultry and to beef are 1.65 and 3.74, respectively, which are very high, particularly when compared to the per capita consumption in the USA. The per capita consumption of pork has been increasing in east Asian countries including China, Korea, and Japan, among which China and Korea have the highest consumption of pork. In 2014, the per capita consumption of beef and poultry in Asia was 43.46% and 59.88% of the world average but was much lower than that in the USA, which accounts for only 11.41% and 14.72%, respectively. In the last decade, the per capita beef consumption decreased in the United States, while it increased in Asia, thereby leading to a decreasing gap. The consumption of poultry per capita continues to increase in Asia, Europe, and the United States, although there are substantial differences in the per capita consumption, particularly between Asia and the United States (Lee et al., 2013). However, Asian countries, including Japan, Korea, Bangladesh, and China, have a higher per capita consumption of fish and seafood than that in the United States.

2. Technological demands of meat processing in China

2.1. Brief introduction of the meat industry in China

At the 58th ICoMST, a review paper by Zhou, Zhang, and Xu (2012) discussed the changes and the status of the meat industry in China. In the past three decades, the meat industry has experienced huge changes, from limited meat availability in the market to being the largest meat-producing country, where initially what were mainly small manual plants are now large-scale companies with modern equipment and technologies, and from just limited meat product types to more than 500 products. The increase in production and consumption of meat and meat products in China is largely due to the rapid economic growth. This is supported by the report of York and Gossard (2004), using data from 132 countries in Asia, Africa, West and Middle East, who found an increase in meat consumption per capita of 2.76 kg/year with each increase in income of $1000. Fig. 3 shows the meat production of China in 1985 and from 2005 to 2014. During the period from 1985 to 2014, the total production increased by 344.70%, while it increased by 30.29% in the past 10 years. In 2014, the meat industry was the largest sector of the food industry, with a share of 12.04%. In China, in that year, the major meat produced and consumed continued to be pork, accounting for 64.07% followed by 14.84% for chicken, 8.00% for beef, 4.95% for mutton, 3.34% for duck, and 2.86% for goose. Pork consumption makes up a high proportion of total meat consumption in China compared with that in Europe and the USA although this share is declining. Therefore, the current policy of Chinese government is "stable development of swine industry, active development of poultry industry and fast development of cattle and sheep industry." In 2014, the total meat consumption in China was 63.12 kg per capita per year, which was 102.31% and 44.27% higher than the average meat consumption in Asia and the world, respectively. However, in China, large differences in meat consumption have been reported between urban and rural consumers, between different regions, and even between different seasons, due to income level, education, meat availability, and tradition (Mao, Hopkins, Zhang, & Luo, 2016). Cole and McCoskey (2013) reported that the annual per capita consumption of the low-income group was less than half that of the high-income group. It has been estimated that the meat demand in China may reach 100 Mt. in 2020 when the country is expected to produce only 90 Mt. The 10 Mt. gap between the estimated production and demand needs to be filled by increased imports in the coming years.

2.2. Technological demands of meat processing in China

2.2.1. Technology demands for fresh meat

China meat industry has not developed well to consistently provide high-quality fresh meat. The major technology demands for fresh meat are to decrease the occurrence of PSE pork and PSE-like poultry and to improve the tenderness of beef.

Quality problems and economic losses of pork and poultry that result from low water-holding capacity have been major concerns of the

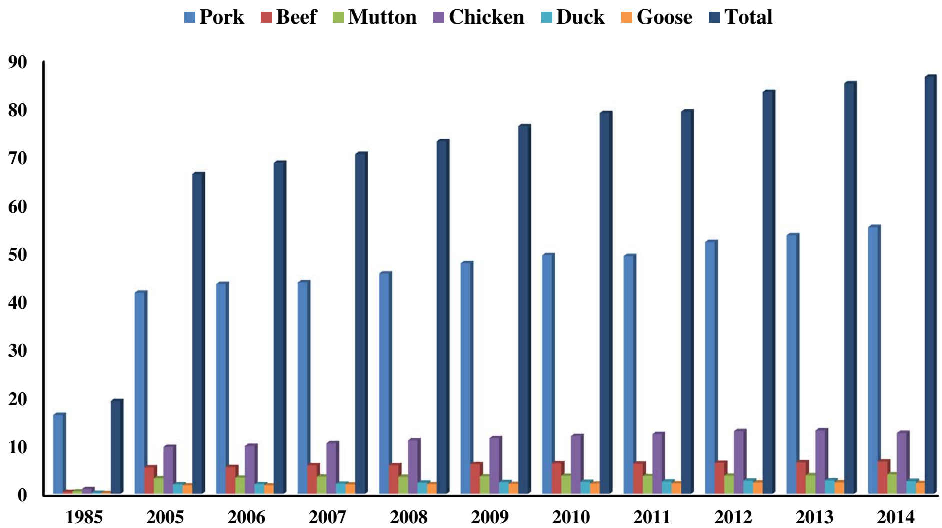

Fig. 3. Meat production in China (Mt.).

meat industry in China. The occurrence of PSE pork is in the range of 10–30%, and the price of PSE pork is 15–20% lower than that of normal pork, thereby leading to several billion RMB losses per year for pork industry (Wang, Shang, & Li, 2012). For PSE-like chicken, a large survey conducted by our research group of chicken slaughtering companies in China found that PSE-like chicken accounted for 20.95% in winter and 23.39% of the total production (Sun, Xu, & Huang, 2012). The percentage of PSE pork and PSE-like chicken in the China industry is higher than those in the USA and Europe. The biochemical mechanisms and the technologies to control the occurrence of PSE pork and PSE-like poultry are well known. However, in China, the meat industry requires more education and training to apply appropriate procedures, including nutrition, transportation condition, pre-slaughter handling, stunning, and slaughtering to lower the rate of PSE pork and PSE-like poultry. Another major concern of the pork industry is carcass weight loss by evaporation during postmortem chilling due to the difference in water vapor pressure between carcass surface and air. Under conventional air chilling methods in China, the water losses of carcasses can be in the range of 1.9–3.5% during the initial 24 h, which is much higher than the 0.75–2% in North America and 1.2–1.7% in Canada (Jones & Robertson, 1988; Prado & de Felicio, 2010). High weight losses of carcasses during postmortem chilling negatively affect the quality and the appearance of pork, thereby leading to huge economic losses in the industry (Zhang, Xu, Zhou, & Li, 2007). Spray chilling has been introduced and well applied in the meat industry in North America, Europe, and elsewhere in the world for beef, pork, lamb, and poultry (Savell, Mueller, & Baird, 2005). This technology sprays cold water on animal carcasses during the initial 3- to 8-h postmortem period to limit water losses from the carcass. However, spray chilling for more than 16 h may have negative effects on carcasses, particularly a washed-out gray or pale appearance (Strydom & Buys, 1995). China meat industry, particularly in medium and small slaughtering plants, has not made good use of spray chilling technology for carcass chilling. Therefore, specific regimes for spray chilling, including duration of spray chilling, amount of water deposition, and size of water sprays, are urgently required by the industry for individual slaughtering plants to reduce water loss of pork carcass.

Tenderness is one of the most important eating qualities for Chinese consumers. A survey showed that the importance of tenderness, flavor, and juiciness for beefsteaks were weighted 0.5, 0.38, and 0.12, respectively, while they were 0.38, 0.41, and 0.21 for beef cooked in hot pots (Mao, 2008). In the same study, they found that the thresholds of shear force for tender and tough beefsteaks were 39.2 and 51.9 N, respectively, and those for beef cooked in a hot pot were 43.0 and 51.3 N, respectively. These values are close to the USDA standards of shear force value of 43.25 N or lower as a beef tenderness certification level (ASTM, 2011). However, the China beef industry is a long way from providing tender beef for satisfying the tenderness demands of consumers. Researches have demonstrated that the shear force values of commercial beef at 7 days of aging were in the range of 48.4–92 N (Hou et al., 2013; Li et al., 2014; Luo, Zhu, & Zhou, 2008; Mao et al., 2012; Zhu, Gao, & Luo, 2011). Most Chinese abattoirs only aged beef for 3 to 7 days before being sent to the distribution chain. Instead of applying the conventional technologies, including breeding, electrical stimulation, and pelvic suspension, fast chilling has been applied, and its use has been recommended by Chinese researchers to improve beef tenderness. Li et al. (2012) used fast chilling to improve beef tenderness and found that beef entering rigor mortis at 14 °C produced relatively tender beef. This finding was confirmed by Liu et al. (2015), who reported that stepwise chilling of beef carcasses entering rigor mortis at 14 °C decreased shear force values. Stepwise chilling includes a fast chilling (− 11 °C; 0.5 m/s) for 2 h, 12–18 °C for 10 h, and followed by a 1 °C chilling (0.5 m/s) to 48 h postmortem. This stepwise chilling process has been suggested as an alternative for the beef industry to decrease toughness and shorten the aging period. In addition, pineapple juice and the enzyme papain were combined with composite phosphates to improve the tenderness of low-grade beef (Huang, Li, & Li, 2009; Tao, Tang, Gong, Qi, & Geng, 2016).

2.2.2. Technology demands for processed meat

There are more than 500 different types of processed meat products in the current market of China. Depending on the current processing technologies, meat products in China generally belong to one of the following categories: smoke and roasted, sausage, dried, ham, deep-fried, cured, sauce-pickled, prepared, and canned products. Among these meat products, Chinese-style products account for 45%, while Western-style products have a share of 55% of the total meat products. Among Western-style meat products, 40% are high-temperature processed products, while 60% are low-temperature processed products (Zhou et al., 2012).

Traditional Chinese meat products have a history of more than 3000 years and many developed by different ethnic groups. Depending on the different flavors, they can be divided as Northern, Southern, Guang, and Chuan styles. These traditional meat products are very popular among Chinese people due to their unique aroma, color, taste, and appearance. However, these meat products that use traditional processing technologies, particularly those produced in family shops or small plants do not provide consistent quality due to the differences in climate, processing procedures, equipment types, and packaging methods. Many traditional processing procedures are based on experience and mainly delivered by masters to students. It is well accepted by the China meat industry and researchers that these processing procedures relating to traditional meat products should be commercialized, modernized, and standardized. This needs to be supported by basic research, in particular, the mechanism by which the unique characteristics of traditional meat products are formed. During this transfer from traditional processing to modern processing technologies, new developed equipment and technologies, including high pressure, ultrasound, online detection, irradiation, fermentation, and modified packaging, are required to be applied for the production of traditional meat products (Li, 2005). These technologies would improve the product consistency and production efficiency, while maintaining the particular quality and sensory attributes of the traditional meat product.

In addition to the requirement for new processing technologies in China, nutrition and health issues of meat products are of high concerns for consumers, particularly those contributing to high intakes of sodium and fat. Sodium chloride is known to be a key factor for the quality and the sensory attributes and for the shelf-life of meat products. However, high salt intake has been proved to be associated with an elevated risk of human diseases (Ruusunen & Puolanne, 2005). A recent report by the Chinese Nutrition Society (2016) showed that the actual intake of salt in China was 10.5 g/day, which is much higher than the daily recommendation of 5–6 g as specified by the World Health Organization (WHO) and the Chinese Dietary Guidelines (2016). Meat and meat products could contribute approximately 16–25% of the total daily salt intake (WHO, 2003). The salt content is high in many Chinese traditional meat products, in particular, in cured meat products. For example, the salt content in traditional dry-cured ham is in the range 6–12%, which is much higher than that in dry-cured ham from European countries. The higher content of salt in traditional dry-cured ham largely limits its consumption and market growth in China. These facts have driven the meat industry to search for technologies to reduce the levels of sodium in processed meat products. Using calcium potassium, magnesium, peptides, amino acids, and phosphates to partially substitute sodium is under study and is partially being applied to dry-cured ham and other meat products in China. Alternative processing technologies to lower the salt content in meat products by improving the extraction and functional properties of muscle proteins and to increase the efficiency of salt distribution are being investigated. The processing technologies that are being investigated include the use of high hydrostatic pressure, ultrasonic-assisted curing and cooking, and beating as substitutes for chopping(Kang, Wang, et al., 2016; Kang, Zou, et al., 2016; Kang et al., 2014; Xue et al., 2016).

Similar to salt, fat also determines the quality of meat and meat products that contributes to the texture, flavor, and juiciness of meat. With Chinese consumers' concerns of the link between diet and human diseases, there has been an increasing interest in consuming low fat, particularly low-saturated-fat meat products. The incorporation of vegetable oil directly into meat products may result in undesirable emulsion capacity and an unstable meat matrix (Youssef & Barbut, 2011). Thus, a pre-emulsification technology has been developed with oil/fat pre-emulsified with meat/non-meat proteins as emulsifiers to partially replace animal fat in processed meat products. Recently, our group studied a pre-emulsified soybean oil emulsion by using sodium caseinate for an emulsified low-fat meat product. By using a pre-emulsification step, the emulsion could be further stabilized using processing technologies, including ultrasound treatment and the addition of regenerated cellulose (Hu, Pereira, et al., 2016; Hu, Xing, et al., 2016; Zhao et al., 2014). Hydrocolloid systems with high water-binding capacity to promote the formation of gels have been examined for their ability to replace fat. Using sugarcane dietary fiber and a combination of carrageenan and soy protein isolate to replace pork fat can provide a low-fat pork batter having improved fat particle–protein matrix (Gao, Kang, Zhang, Li, & Zhou, 2015; Gao, Zhang, & Zhou, 2014; Gao et al., 2016; Zhuang et al., 2016). In addition, the application of high hydrostatic pressure to meat batters prior to cooking has the potential to lower the fat level of emulsion-type sausages by enhancing thermal gelation and improving gel structure (Yang et al., 2016).

3. Technological demands of meat processing in India

3.1. Brief introduction of the meat industry in India

India is an agrarian country with approximately 60% of its people depending directly or indirectly upon agriculture. Livestock plays an important role in the Indian economy and provides livelihood to two thirds of the rural community. Livestock, including cattle, water buffalo, sheep, goat, pig, and chicken, is primarily reared for milk, meat, egg, and draught power. A few other species, including yak, mithun, camel, rabbit, duck, emu, and Japanese quail, are also reared in some parts of India as livelihood activities. There are approximately 42 sheep breeds, 26 goat breeds, 13 buffalo breeds, 40 cattle breeds, 6 pig breeds, and 17 chicken breeds registered with the Indian Council of Agricultural Research-National Bureau of Animal Genetic Resources (ICAR-NBAGR). In 2014, India had a vast livestock wealth and ranked 1st, 2nd, 3rd, and 4th in the world for water buffalo, cattle, goat, and sheep numbers, respectively (FAOSTAT). In the year 2013, India produced 6.21 Mt. of meat, which is the largest amount of buffalo meat produced in the world (43.33% of total). It was also the world's 3rd largest producer of goat meat. Per capita consumption of meat in India remains relatively low, i.e., less than 5.5 kg/person/year.

India has about 4000 registered slaughterhouses that are maintained by local authorities where animals are slaughtered for domestic consumption. Slaughtering is performed in designated abattoirs or slaughterhouses, and most of the meat is consumed on the day of slaughter or kept in a refrigerator in the households. The meat produced for the domestic market is sold as hot meat (pre-rigor meat without any chilling). The Food Safety and Standards Act (2006) enacted by the Food Safety and Standards Authority of India (FSSAI) ensures the production of hygienic meat for domestic consumption. Buffalo meat is mainly processed in state-of-the-art export abattoirs. In the years 2015 and 2016, India has exported 1.47 Mt. of frozen buffalo meat and by-products worth USD 4.0 billion, thus making it the single largest agricultural commodity exported from India (APEDA, 2017). According to the All India Meat and Livestock Exporters Association (AIMLEA), there are 65 export abattoirs-cum-meat-processing plants in India registered with the Agricultural and Processed Food Products Export Development Authority (APEDA), and they employ 74,000 individuals directly and 150,000 individuals indirectly. India is exporting meat and meat by-products to 85 countries around the world. India's poultry sector represents one of the biggest success stories of the country over the past decade. Poultry meat is mostly sold by slaughtering live birds in the presence of consumers in wet markets, and this comprises almost 91% of total broilers. However, in the recent years, the demand for chilled and frozen poultry meat, and portioned cuts, is also increasing, thus resulting in more than 21 modern poultry-processing plants with a capacity to process about 1000 to 6000 birds per hour and about 15 smaller processing plants with a processing capacity of less than 1000 birds per hour.

3.1.1. Technology demands for fresh meat

Cattle and buffalo are primarily reared for milk production and are slaughtered for meat production after their productive and reproductive life ends. Sheep, goat, and pigs are reared mainly for meat production by using extensive and semi-intensive methods. For domestic consumption, cattle and buffalo weighing approximately 250–300 kg are usually slaughtered on the floor as per halal requirements. Sheep and goats, which weigh approximately 15–25 kg live weight, are normally bled on the floor without any stunning; however, all the remaining dehiding and dressing operations are performed using overhead rails. The slaughterhouses maintained by local bodies, also referred as service abattoirs for the production of meat for domestic consumption, are old and lack facilities for hygienic slaughter and dressing of food animals. These abattoirs do not have cold storage, packaging, effluent treatment, or rendering facilities. This results in poor use of animal byproducts and disposal of slaughterhouse waste, thus causing environmental pollution. The slaughterhouse byproducts, except for hide and skin, are in an unorganized sector, and there is a scope for value addition for increasing profit margin. Recently, government agencies have established a few modern abattoirs in select metro cities to cater to domestic consumers. However, large numbers of meat industry personnel and butchers working in these abattoirs resist using modern online slaughtering and dressing operations and continue to use floor-slaughter methods. Therefore, concerned agencies are now considering semi-modern abattoir designs, which suit Indian requirements and require less monetary inputs. Grading of animals, suitable transportation methods, and technologies for humane slaughtering for ensuring animal welfare need to be addressed. Technology upgrade and investments are required in the area of waste disposal, development of high-value products from slaughterhouse byproducts, and biogas production. Appropriate packaging and efficient chilling and freezing, including super-chilling technologies, are required to augment clean and hygienic meat production. Slaughterhouse effluent treatment and solid waste management are some of the areas that need better technological intervention.

Considering these challenges, researchers in India have developed technologies for improving the fresh meat quality, shelf-life, and safety and sensory attributes, especially texture from different meat animals and poultry. Muscle-specific variation in buffalo meat texture (Kiran et al., 2015) and tenderness variability and aging changes in young and old buffalo meat (Kiran et al., 2016) have been studied. Investigations have been conducted to improve the tenderness of meat produced from spent buffaloes by using plant proteases such as *Cucumis trigonus roxb*, *Zingiber officinale roscoe*, and papain, which are injected into the carcasses (Naveena, Mendiratta, & Anjaneyulu, 2004), and chemicals such as ammonium hydroxide (Naveena, Kiran, et al., 2011). Proteomics of buffalo and goat meat color and lipid-induced oxidation has been reported recently by Naveena, Usha Rani, Praveen Kumar, Kulkarni, & Rapole (2016). Researchers have also reported improvement in the storage stability and the quality of ground buffalo meat by using sodium ascorbate (Sahoo & Anjaneyulu, 1997) and rosemary phenols (Naveena et al., 2013). Shukla, Kandeepan, and Vishnuraj (2015) have developed an on-package indicator sensor for measuring the total volatile basic nitrogen released from buffalo meat during refrigerated storages. Very often, adulteration of sheep and goat meat with buffalo meat or beef has been reported in India. Researchers have developed highly accurate and efficient molecular techniques by using polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP), together with several immunological methods, of mitochondrial 12S rRNA gene (Girish et al., 2004). Girish, Kulkarni, Sen, and Muthukumar (2014) have demonstrated a traceability model in the buffalo meat-value chain, mainly for use in export abattoirs.

3.1.2. Technology demands for processed meat

The total meat-processing capacity in India is over 2 Mt. per year, of which only 40–50% is used and 85% of this comprises frozen buffalo meat mainly for export. Further processing and value adding of meat in India remain less than 2% with the exception of poultry, where about 7.2% of meat undergoes processing. To increase the meat production, processing, value addition, and consumption, the availability of cheaper, durable, and simple meat-processing machineries is a prerequisite. However, only very few companies in India manufacture slaughter or meat-processing equipment. Imported processing equipment is very costly, and no qualified service personnel are available for after supply services. In the absence of adequate local manufacturers and the higher costs involved with imported equipment, it is difficult for start-up entrepreneurs to venture into the meat-processing business. Because of the nonavailability of cheaper, local meat-processing equipment, most of the existing meat processors are mainly using imported machinery such as automatic deboning machines, slicers, mincers, grinders, bowl choppers, tumblers, patty making machines, batter applicators, multineedle injectors, and smoke chambers. The meat-processing equipment market is driven by the possibilities such as increased consumption of processed meat and better quality of meat products. However, the lack of awareness of processing equipment and the availability of trained manpower in India are the main obstacles to the growth of the meat-processing market. Technological interventions are required in the area of processing of shelf-stable meat products, fermented and dried meat products, and specialty meat products having local flavors and tastes.

Even though cultural patterns, rather than income, dominate meat consumption in India, the ready-to-eat meat sector is growing with consumer affluence. Presently, the value-added meat product sector in India is restricted to poultry meat products. Approximately 20–25 medium-scale meat processors and 8–10 multinational food chains operate through direct retailing or franchise for various value-added meat products, including sausages, burger patties, lollipops, chicken drumsticks, nuggets, and various traditional meat products. However, such initiatives for sheep, goat, and large animal meat are almost absent except for pork, whereas few processors manufacture ham, bacon, picnic, and others. The evolution of modern retail outlets with better packaging, labeling, chilling, and cold chain facilities will hopefully address the drawbacks of the existing situation.

Researchers in India have developed processing strategies for various value-added meat products with an emphasis on the use of meat from culled and old animals and spent poultry. Buffalo meat has been used in the production of various value-added meat products including sausages, meat loaves, burger patties, corned-buffalo meat, and cured and smoked products (Anjaneyulu, Thomas, & Kondaiah, 2007). Acceptable buffalo meat emulsions and restructured buffalo meat nuggets have been stored for up to 20 days at 4 ± 1 °C under aerobic conditions (Thomas, Anjaneyulu, & Kondaiah, 2006). An investigation exploring the possibilities for the commercial utilization of buffalo liver in comminuted meat products was reported by Devatkal, Mendiratta, and Kondaiah (2004). Preparation of chicken nuggets, sausages, and various other value-added products by using spent hen meat and poultry byproducts has been reported by Naveena, Muthukumar, Anjaneyulu, Sen, & Kondaiah (2011). Processing of sous-vide chicken sausages (Naveena, Panjab, et al., 2016), pork nuggets incorporated with fermented bamboo shoot (*Bambusa polymorpha*) mince (Thomas, Jebin, Barman, & Das, 2014), and restructured mutton nuggets enriched with grape seed extract (Bhaskar Reddy et al., 2013) have been reported. In addition to these value-added meat products, diversity in culture and tradition has resulted in a wide range of local meat and poultry products spread across India. Large numbers of micro, small, and medium processors are involved in the production of a wide range of traditional meat products as mentioned in Table 1 (Reddy, Bhaskar Reddy, & Muthukumar, 2010). Many of these local meat products are going global and are providing good opportunities and scope for export.

With a population of over 1 billion and a 350 million-strong urban middle class with changing food habits, the processed food market is

Table 1
Region-specific traditional meat products of India.

Region	Name of the meat product
Northern India	Seekh kebab, Tandoori chicken, Goshtaba, Nate-Yakini, Tabak manss, Rista, Aba gosh, Rogan josh, Balti meat curry
Eastern India	Meat dopiaza, Momo, Kargyong, Suka ko maso, Satchu, Kheuri, Ngam phoat, Doh pheret, Arjia, Chartayshya, Chilu, Gemma
Western India	Meat rolls, Vindaloo, Shakudi, Mutton Kolhapuri
Southern India	Chettinad chicken, Haleem, Biryani, chicken curry, dry salted meat, meat curries, meat pickle, meat Vindaloo

promising a huge potential to be tapped. The demand for meat and meat products continues to be high in India and will be the key driver for livestock sector. Emerging consumption of convenience and value-added meat products will not only diversify the food production system but also provide huge employment opportunities to large number of micro-, small-, and medium-scale entrepreneurs.

4. Technological demands of meat processing in Korea

4.1. Brief introduction of the meat industry in Korea

As with other Asian countries, the Korean people have traditionally consumed mainly grains, rice, and vegetables, while rarely consuming meat or meat products because of the importance of livestock for farming in agricultural sector. Consequently, old cattle were slaughtered as a meat source and recipes, such as *bulgogi*, thinly-sliced, and marinated beef, were developed to make beef tender and look plentiful. In the 1960s, the industry of meat and meat products emerged with the policy of promoting the livestock industry. In the early 1980s, large companies started to enter the Korean meat-processing industry, and the Korean industry was modernized and systemized. Along with the rapid growth of the national economy and household income, per capita meat consumption also increased. The per capita meat consumption in 2015 was 47.1 kg, which was more than 9 times of that in 1970 (5.2 kg) (KMTA, 2016). The proportion of the livestock industry in the whole agricultural sector has reached approximately 40%, and 6 out of the top 10 categories of production in agriculture are from animal origin including pig, Hanwoo (Korean native cattle), chicken, milk, egg, and duck in decreasing (MAFRA, 2015).

The supply and production of meat has increased gradually since 2004 (Fig. 4), and meat and meat products sector now represent 1.5% of the total GDP and 5.4% of the GDP in the manufacturing sector in Korea (MFDS, 2016). Approximately 70% of meat in Korea is native produced although the proportion of self-supply has fluctuated across the years. However, recently, this figure is trending lower because of the considerably lower prices of imported meats, positive treatment of animal diseases, and the international trade environment. In the meat industry, packed fresh and processed meat accounted for 2.15 and 0.97 Mt. in 2015, respectively (MAFRA, 2015), which shows grilling or barbecuing fresh meat is a predominant cooking style of Korean consumers. However, the amount of processed meat production and consumption also increased slightly by years in the order of sausage, ham, bacon, mixed sausage, and canned products in 2015.

By the 2000s, the meat industry in Korea reached a plateau in their size because of the changing consumer perceptions regarding meat and meat products. Continuous outbreaks of livestock-related diseases, including bovine spongiform encephalopathy, foot-and-mouth disease, and avian influenza, nationally and/or internationally have led to consumer concerns about the consumption of meat and meat products. During the period from 2010 to 2011, 3.5 million cattle and pig and 6.5 million poultry were killed due to foot-and-mouth disease and avian influenza, respectively, which consequently affected the national economy and the livestock industry in Korea. In addition, many studies including the announcement of the WHO in 2015 have reported the possible positive relationship between health risks and excessive red meat consumption. These series of events increased the negative perception of consumers for the consumption of meat and meat products, thus leading to an increased demand for changing products, production methods, and regulations in Korea. New technologies for animal treatment, meat production, quality control, distribution, processing, and management, including carcass grading, HACCP, and complete cold chain have been introduced and successfully implemented in response to the international market changes such as Free Trade Agreement.

4.2. Technological demands of meat processing in Korea

4.2.1. Technology demands for fresh meat

Fat in meat and meat products significantly improves the eating quality, especially tenderness and flavor. Therefore, in Korea, marbling is one of the most important factors to judge quality grade in meat. However, many consumers avoid visible fat due to health concerns (Frank, Joo, & Warner, 2016). An inconsistency between the consumers' intended purchase and the actual purchase for highly marbled beef has been reported because of the conflict between health and taste requirements of consumers (Font-i-Furnols & Guerrero, 2014; Torrico et al., 2015). Although the recent debate on marbling suggested that intramuscular fat contained high levels of poly- and mono-unsaturated fatty acids, which could be beneficial to human health (Troy, Tiwari, & Joo, 2016), it is still necessary to implement technologies for enhancing tenderness and flavor in low-marbled or low-graded meat with unique and characteristic quality for consumers. Recently, the Korean meat industry also searched for a market to export high-quality meat, especially Hanwoo beef, to neighboring countries such as China. Currently, three technologies are being urgently demanded from the fresh meat industry in Korea, including meat tenderization, meat-value

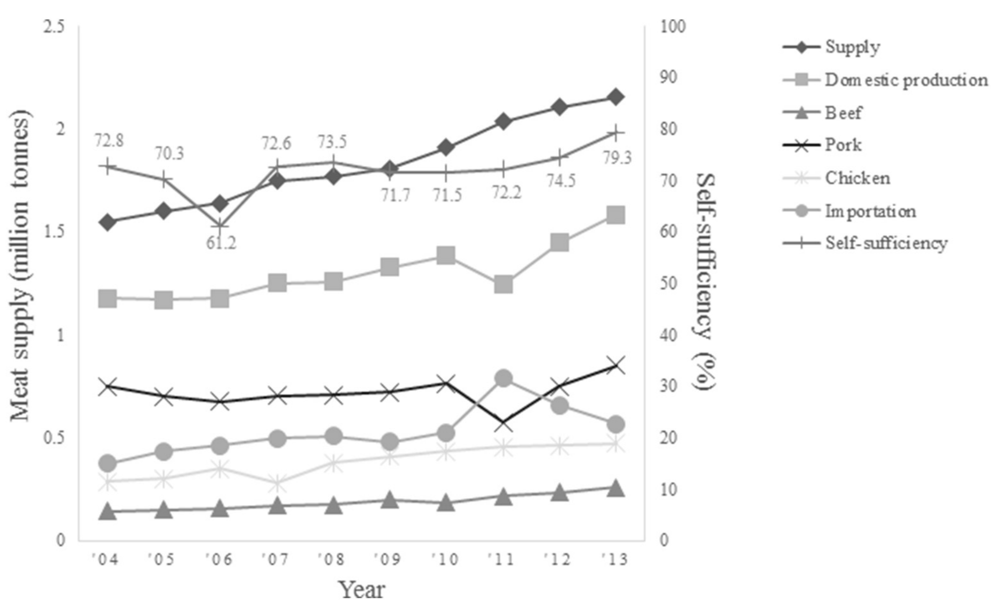

Fig. 4. Supply, production, import, and self-sufficiency of meat in South Korea (KMTA, 2016).

addition, and quality management.

The technologies that can be introduced and implemented to satisfy consumer's demands in terms of tender beef, without high intramuscular fat, are hot boning and electrical stimulation, which have been widely used in Australia and New Zealand. The mode of action and advantages and disadvantages of the methods are relatively well known. Furthermore, newly developed technologies such as stepwise chilling and hydrodynamic pressure processing can be applied to achieve meat tenderization. These technologies may provide additional benefits including energy savings during the chilling of carcasses and antimicrobial activities. These technologies have not yet been used in the Korean industry, but it is expected that they could soon be applied through research.

Korean consumers prefer to purchase highly marbled and high-quality-graded meat because of the tender texture and improved flavor after grilling in the meat. Therefore, low-marbled cuts are downgraded and avoided by consumers, thereby leading to an economical imbalance and great loss for the meat industry (Kim, Seo, Lee, Kwon, & Jun, 2010). Traditionally, dry aging has been used to improve the palatability of beef and is currently being applied for the production of value-added meats by using low-marbled and low-graded beef. The flavor development in aged meat is the result of lipid oxidation, Maillard reaction, and inter-reactions of lipid oxidation and Maillard reaction products. Many pre- and postmortem factors during aging are known to affect the quality of aged meat (Khan, Jung, Nam, & Jo, 2016). Because dry aging is processed in aerobic conditions, it results in significant weight and trim losses. Therefore, it is necessary to find the optimal conditions for the aging process in terms of both economical and quality aspects in industry application. In addition, such processes should be accompanied with safety assessments for the consumption of aged meat during the aging process and/or after the completion of aging and further storage. The establishment and the update of regulations related to dry aged meat should be supported for commercialization. Recently, not only beef but also pork was tested for the application of dry aging, and it was found that the dry-aged pork loin also had improved textural and sensorial qualities (Lee et al., 2016). Another value addition of meat that the industry is currently commercializing is to increase beneficial elements in meat by feed incorporation, such as n-3 fatty acids, minerals, and vitamins. Additionally, recent consumers' awareness of animal welfare is one of the quality criteria that can be considered as added value.

Ready-to-cook packaged fresh meat is a main product for domestic use and export in Korea. Therefore, packaging methods and materials should be improved by the combination of recently developed technologies. The changes in microbiological or physicochemical quality of meat should be suppressed and precisely monitored during transportation and storage.

4.2.2. Technology demands for processed meat

The recent demands of the production of safe and high-quality meat products combined with relatively new concepts of all-natural and clean-label have increased in the Korean market (Jayasena & Jo, 2013). These meat products may contain natural or organic ingredients without synthetic preservatives that do not cause common food allergies or sensitivities (Mariutti, Nogueira, & Bragagnolo, 2011). The classification of the International Agency for Research on Cancer (IARC), the cancer agency of the WHO, that excessive processed meat was carcinogenic to humans may further increase the consumer demand to avoid synthetic additives. However, meat industry is also striving to ensure the safety of meat products for consumer. Thus, three technologies for processed meat products are demanded in Korea including natural additives, reduction of toxic compounds, and preservation technologies for processed meat products.

Numerous studies have been conducted and reported, but natural materials that could successfully replace synthetic additives are limited in processed meat manufacturing. For example, to successfully replace sodium nitrite, the substitution of nitrite by natural sources should have comparable characteristics without causing any health hazards or quality deterioration. These attempts, however, remain unsuccessful in identifying an effective single replacement material possessing all the properties of nitrite, including antimicrobial activity especially against *Clostridium botulinum*, antioxidant activity, color development, and flavor enhancement (Sindelar & Milkowski, 2011). Therefore, the development of an additive technology by using natural sources is highly demanded in the Korean meat industry.

Practical technologies that can minimize the production of harmful substances during the processed meat manufacturing, including N-nitroso compounds, polycyclic aromatic hydrocarbons, and heterocyclic amines, should be developed and implemented in meat industry. Even though the amounts of these compounds in processed meat are negligible and may have no effect on human health, the minimal production of these compounds by continuous improvement of processing technologies could provide consumers with increased satisfaction and confidence. In terms of nitrite alternatives, hurdle technologies for meat curing can be applied by combining low levels of nitrite and processing technologies possessing inhibitory activities against pathogenic microorganisms as a hurdle (Alahakoon, Jayasena, Ramachandra, & Jo, 2015). Polycyclic aromatic hydrocarbons can be reduced by processing at a smoking temperature below 400 °C (Simiko, 2005) and by using a wet smoking method, which has not yet been well applied in the Korean meat industry.

Recently, a rapid increase in processed meat in the export market, especially "*samgyetang*," makes the industry focus more on the safety of meat products without compromising quality. *Samgyetang* is a traditionally prepared cuisine in Korea by using a young chicken braised in a soup with various oriental medicinal herbs, including ginseng, and is consumed especially during the summer to overcome heat (Nam et al., 2010). Advanced technologies such as high pressure, pulsed electric field, ohmic heating, radio frequency, and others have been developed and partly commercialized in the industry. Therefore, the Korean meat industry may adapt these technologies in their production line to ensure the safety of processed meat products.

5. Technological demands of meat processing in Japan

5.1. Brief introduction of the meat industry in Japan

After Japan opened up to foreign visitors and trade 160 years ago, meat was initially consumed only by limited classes of people and considered as a very luxurious meal. In the Meiji period (1868–1912), the new government promoted the development of the animal industry and the production of meat, milk, and eggs for the improvement of physique and nutrition of Japanese people (Sakata, 2010). During these early days, meat-processing methods and techniques were transmitted from European countries such as England, but the diffusion of skills and knowledge was limited to a few places around ports connected to foreign trade including Nagasaki and Yokohama. In the beginning of modern meat processing in Japan, skills were imparted by the First World War German prisoners. At that time, there were a few Metzgers (butchers) by profession, and they taught their meat-processing techniques in the camp (Sakata, 2005). Thus, German-style products were subsequently developed in Japan, including frankfurters, wieners, and many types of smoked and cooked sausages and ham. Therefore, the processing machines in the Japanese industry are still now mostly imported from Germany, and German-style products continue to be produced in Japanese meat companies. The per capita consumption of Japan was 30 kg/year in 2014 and pork, beef, and chicken accounted for 40%, 20%, and 20%, respectively.

5.2. Technological demands of meat processing in Japan

5.2.1. Technology demands for fresh meat in Japan

Traditional methods of agriculture, food preference, and attitudes have undergone considerable changes for fresh meat in Japan. By breeding programs, a very special breed of cow, known as “Wagyu” (Japanese black cattle), has been developed by farmers and the animal industry. The most outstanding and prominent feature of Wagyu meat is its marbling due to the fine accumulation of fat in the muscle, which leads to the gloss and fine color of the meat. The fibers of the meat contain many fat cells and much fatty tissue. In Japan, cattle carcass quality assessment is primarily based on the degree of marbling in the loin between the 6th and 7th ribs. According to this criterion, a model of Beef Marbling Standard has been established for use by an official panel of judges to provide accurate indication of the extent of marbling. Recently, dry aging of Wagyu meat has been developed by Japanese butchers, with carcass aging for 2 weeks in cool temperature to obtain a special aroma. However, with more than 2 weeks of storage, there tends to be a decrease in its desired fine aroma and an increase in a fermented aroma.

In Japan, pork is produced in larger quantities by using a deboning machine developed by the Japanese meat industry (Fig. 5). A demonstration of this machine was performed at the 45th ICoMST in Yokohama in 1999, and since then, various improvements have been made. This is an auto-slitting and deboning system for pig thigh (Fig. 2). It is a mechanized slitting process to enable optimal knife control within vertical multijoint robots. This system gives a higher yield than that generally achieved by human workers.

5.2.2. Technology demands for processed meat

In Japan, food additives are divided into 449 synthesized types and 365 types derived from natural sources. These additives, together with various other ingredients in meat products, are likely being used not only in Japan but also in other countries. This is as expected because Japanese processing technology has traditionally come from Germany and other Western countries (Sakata, 2015). Nevertheless, there are certain substances peculiar to Japanese hams and sausages such as fermented soy, which is an extract considered an umami substance that is not often found in meat products in other countries. These substances are now known worldwide as important determinants of meat flavor. Nitrite and nitrate are used in the Japanese meat industry to enhance the red color of meat, but at present, their amounts have been reduced as a safety consideration and alternative agents are being sought for this purpose (Sakata, 2014). These two compounds not only improve the red color of meat but also control bacterial growth. They have been found particularly effective for warding off the effects of botulinum, acting as anti-oxidants, and maintaining desirable meat flavor. Nevertheless, consumers tend to demand the exclusion of chemicals such as nitrite and nitrate because there is a suspicion of their possible involvement in carcinogenic effects. Accordingly, whey protein hydrolysates have been examined for their capacity to serve as color formation accelerators in meat products such as hams and sausages and to determine the extent to which they may serve as heme pigment stabilizers (Sakata, 2010). Consequently, efforts have been continuously made to devise methods for meat reddening without the use of any nitrite or nitrate (Suman, Hunt, Nair, & Rentfrow, 2014). Natural salts, particularly those found in Himalayan rock salts, appear to be the most promising candidates for use in meat reddening owing to their mineral content (Kaneko & Sakata, 2014).

High pressure processing is an alternative to thermal treatment for the production of safe meat and meat products, while retaining their quality and freshness. High pressure does not depend on heat, chemicals, reduced water activity, or reduced temperatures to control pathogens or spoilage microorganisms. In contrast to heat, high pressure does not break covalent bonds and is transferred instantly throughout a package of food independently of size, shape, or composition. These advantages give the food processing industry an almost ideal technology to preserve food without heat and to conserve the product without losses of original nutrients, flavors, pigments, or functionality (Farkas, 2016). In the 1990s, the mechanism for meat tenderization and acceleration of postmortem aging of meat induced by high hydrostatic pressure was demonstrated (Suzuki, 1995). Subsequently pressure-induced gelation of meat (Iwasaki, Washio, Yamamoto, & Nakamura, 2005) and structural weakening of intramuscular connective tissue (Ichinoseki, Nishiumi, & Suzuki, 2006) were also reported. These studies contributed to improve the texture and the palatability of meat and meat products by using high pressure processing technology or the combination of high pressure with sodium hydrogen carbonate (Kim, Nishiumi, Fujimura, Ogoshi, & Suzuki, 2013; Ohnuma, Kim, Suzuki, & Nishiumi, 2013; Tabe et al., 2013). At present, commercially available high pressure-processed meat products come from countries all around the world, including Japan, the United States, Italy, Spain, Germany, and Australia (Guillou, Lerasle, Simonin, & Federighi, 2017). In Japan, high pressure-processed meat products such as sausage, bacon, and sliced ham with prolonged shelf life and produced without the use of either nitrite or preservatives have been marketed since 2005.

6. Conclusion

In the past decades, meat production and consumption has been steadily increasing in Asian countries. This trend is expected to continue in the near future with the consistent development of economy, population, and urbanization, particularly in China. However, the levels of industrialization, standardization, and modernization of meat industry vary among Asian countries and even in different regions of the same country. Many Asian countries do not have well-developed technologies and standards for assuring the quality of meat and meat

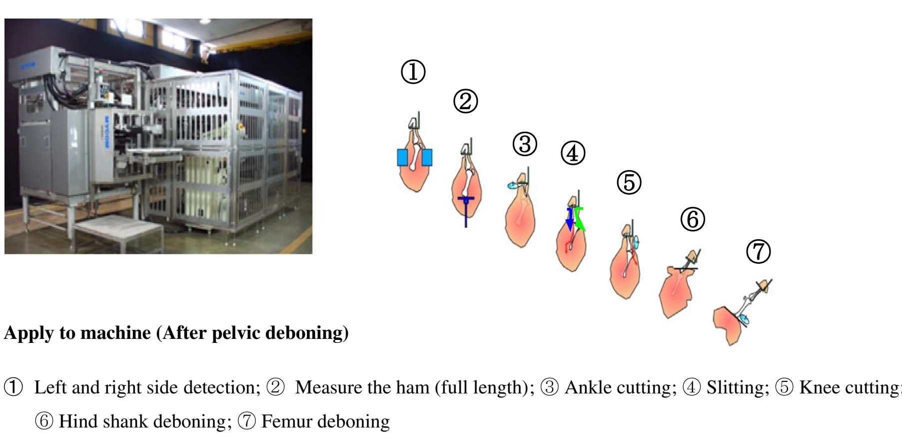

Fig. 5. Photo and illustration of deboning machine developed by the Japanese meat industry (MYCOM, http://www.mayekawa.com/products/features/hamdas-r/). Apply to machine (after pelvic deboning). ① Left and right side detection; ② Measure the ham (full length); ③ Ankle cutting; ④ Slitting; ⑤ Knee cutting; ⑥ Hind shank deboning; ⑦ Femur deboning.

products when compared to the Western countries. The acceptance and application of new technologies is partly limited by the legislation and regulation of government, lack of knowledge of meat industry, and acceptance of consumers. However, most of the emerging innovative and sustainable technologies and equipment to improve meat quality and ensure meat safety are highly demanded in Asia in the near future.

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