CHAPTER 5

Discussion and Conclusions

5.1 Discussion

5.1.1 Poultry production systems and type of slaughterhouses

Corresponding to the observation in this study, poultry in rural areas in developing countries are raised to serve household food demands and obtain additional sources of income (Conan, Goutard, Sorn, & Vong, 2012). In Thailand, native chickens are mainly indigenous, sometimes mixed with other breeds, generally raised in rural areas under free-range conditions. The birds play an important role of yard cleaners by converting leftovers from human consumption and agricultural by-product to meat (Choprakarn & Wongpichet, 2007). Native chickens can freely move with their flock scavenging around households or agricultural fields for edible insects, human leftovers, seeds and parts of fresh plants, described as a scavenging system of poultry production. Other systems included a free-range system in which poultry is provided with additional feed and night-time housing and a semi-commercial system in which poultry are provided with feed and water as well as kept in fenced-in areas (Rushton & Ngongi, 1998 (as cited in Kryger, Thomsen, Whyte, & Dissing, 2010)).

In general, vaccinations and deworming drugs are not mainly used for native chicken rearing. However, some farmers use local herbs for disease prevention and treatment (Choprakarn et al., 1983; Klinhom et al., 2005; Laopaiboon, 1990 (as cited in Choprakarn & Wongpichet, 2007)). In addition, high chance of getting diseases and exposure to predators resulting in low number of productivity (Kryger et al., 2010). There was no obvious practice for raising of native chickens. Raising one batch of native chickens takes longer time than commercial systems. It can be several months or up to a year depends on households to make a decision to sell or slaughter in times of need. Refer to the FAO classification of poultry production systems based on a biosecurity-based classification, backyard poultry is mostly raised in minimal biosecurity systems (sector 3 and 4) where almost 99% of producers were in these categories (Chantong & Kaneene, 2011).

Different from traditional system of backyard raising, commercial broilers are from western (Aviagen, Cobb, and Hubbard) and mixed-native backyard breeds (Chantong & Kaneene, 2011). Most of day old chicks are bred from large integrators and distributed to contract farmers. Developing in technology that have improved genetics, farm managements and feed nutrition results to shortened period of broiler raising to around 40 days (NaRanong, 2007; USDA Foreign Agricultural Service, 2014). Biosecurity measures and compartmentalization were employed to the broiler industry after an avian flu outbreak. The open housing system was converted into the closed system to ensure high levels of safety as well as minimize contact and contamination (NaRanong, 2007, Ipsos Business Consulting, 2013).

Data from the Thailand Information and Communication Technology Center (2015) showing that the number of native chickens was higher than broiler (2.5 million and 1.5 million, respectively). The production of chickens in Northern Thailand was highest in Chiang Mai province. Backyard slaughterhouses in Chiang Mai were underestimated in the number since operation with this type most of the owners arbitrarily set up their own slaughterhouses and used facility within their households. The sources of chickens were coming from small farms or backyard rearing which most chickens were mainly native breed. Birds supplied to this type of slaughterhouse usually come from free-range or semi-intensive systems with open housing that birds are more likely to expose to the environment than those raised in intensive farming system supplied to commercial slaughterhouses.

The reasons that chickens from small producers cannot be processed to the commercial slaughterhouses because those plants cannot keep track on a small batch of birds and cannot make money on small orders (Fanatico & Ellis, 2017). Thus, chickens produced from small producers, including backyard raising were processed to backyard slaughterhouses. Compared to the study of Fanatico and Ellis (2017) in the United States, backyard slaughterhouses defined in this study can be compared to the small type of processing with year-round operation. However, slaughter operation in Chiang Mai had very less slaughter capacity per day when compared to the cited study that had a capacity

200-5,000 birds per day for the small type of processing. The slaughter capacity of the commercial slaughterhouses defined in this study also had less capacity when compared to slaughterhouses in integrated industry that had capacity of over hundred thousand per day (USDA Foreign Agricultural Service, 2014; Fanatico & Ellis, 2017).

In commercial slaughterhouses, electrical stunning by a low voltage system was employed to the chickens for immobilization before slaughtering. Other stunning techniques can be used according to the Thai agricultural standard of good manufacturing practices for poultry abattoir, such as gas stunning (carbon dioxide, argon) and other methods authorized by competent authority and internationally recognized (Thailand Ministry of Agriculture and Cooperatives, 2006). Cutting blood vessels in the neck and bleeding is the standard procedure used in the slaughtering operation. After transport birds to slaughterhouses, birds are removed from the crates and hung on an overhead shackle. In some small-scale plants, birds were placed in funnel-shaped kill cones before stunning (Silverside & Jones, 1992; Fanatico & Ellis, 2017). The slaughtering step was different in backyard slaughterhouses within this area. The method used at each slaughterhouse was based on the owner’s experience. Moreover, local believes and preference of consumers also affected the way of slaughter processes. Most of the owners preferred using the methods such as neck hanging or cervical dislocation rather than throat cutting since the latter method drained all the blood out and given the carcass pale color. Using the methods that preserved the blood inside the chicken body made the carcass in pink color, and most of the customers preferred to buy this kind of chickens due to perception of fresh meat.

Low- and high-care area separation was one characteristic that backyard different from commercial plants. Regarding to the Thai Agricultural Standard, low- and high-care area (dirty and clean zone) separation were clearly defined for the GMP for poultry abattoir (Thailand Ministry of Agriculture and Cooperatives, 2006). The low-care area starts from the stunning operation to carcass washing and the high-care area starts from chilling to the step of packaging. In commercial slaughterhouses, the slaughter process in each slaughterhouse was similar because of the plants were designed according to the recommendations of GMP standard. Some settings were slightly different such as voltage and time used at the stunning step, bleeding time, which depended on line speed and length of the stunning line, temperature and time used at each step namely scalding and defeathering. In backyard slaughterhouses, the backyard area was utilized for a whole slaughter process. Areas used for operations were not obviously separated for each step because of low investment and low slaughter capacity.

From a survey and data collection on slaughterhouse management and operation, 50% (2 of 4) of backyard slaughterhouses immediately processed chickens after receiving without resting. Feed withholding should be done for 8-12 hours before slaughter to reduce the amount of contents in the gut and the possibility of intestinal laceration during the processing (Fanatico & Ellis, 2017). However, taking too long time of withholding can result in stress and watery guts that have potential to leak.

Water temperature in scalding tanks from backyard and commercial plants were different. However, the temperature was higher than that recommended in the GMP standard that shall be 58 ^{o}C or higher (Thailand Ministry of Agriculture and Cooperatives, 2006). Water source used in backyard slaughterhouses was the same source used in the households while in commercial plants, ground water treated with chlorine 0.5-1 ppm was used for all operations including scalding, washing, chilling steps as well as equipment cleaning. Water sources used in both types of slaughterhouses assumed to be treated with chlorine. However, in this study, water sample collection was not done for quality test.

Carcass washing and chilling were the steps distinctively operated in each type of slaughterhouses. In commercial plants, inside and outside carcass washing was performed after evisceration using machinery or human power followed the GMP for poultry abattoir (Thailand Ministry of Agriculture and Cooperatives, 2006). In backyard plants, immersion of all carcasses in the same tub was performed instead of one by one carcass washing. The owners have given the reason they immersed the carcasses in a tub because after passing scalding step, the water at room temperature will tense the chicken skin and made the carcass in a fresh condition as the consumers' perception.

A chilling process in backyard slaughterhouses was based on the time that the fresh markets in that area were operated. If the owner can transport and sell meat products after slaughter process, chicken carcasses or parts of carcasses will be packed in plastic bags and transported to the market immediately without chilling otherwise they will be kept in cooler box with ice to prolong the shelf life as the main purpose to preserve meat products to sell in the afternoon or the next day. There are two main chilling systems generally used in the commercial slaughterhouses; immersion chilling and air chilling. Immersion chilling is the process generally performed in the United States, while air chilling is most popular in European countries, Brazil and Canada. Both chilling systems have advantages and disadvantages on carcass quality and safety. Water absorption (4-6%) can occur in immersion chilling while there is no moisture pickup or loss from air chilling. However, 1-1.5% weight loss can be commonly found from air chilling (Demirok et al., 2013). In this study, immersion chilling in cold water and ice was employed to decrease the core temperature of carcasses. The core temperature of carcasses from data collection corresponded to the Thai agricultural standard of good manufacturing practices for poultry abattoir that lower than 7 ºC (Thailand Ministry of Agriculture and Cooperatives, 2006).

Weight of the carcasses obtained from backyard and commercial slaughterhouses were different, 1.0 and 1.9 kg, respectively. The slaughter weights of carcasses from both types of slaughterhouses corresponded to the study of Jaturasitha et al. (2002) that investigated productive performances of Thai native chicken and broiler. The chickens in the study were slaughtered at market size and the slaughtered weights of native chicken and broiler were approximately 1.2 and 1.9 kg, respectively. Low growth efficiency and poor performance of native chickens raised in a free-range system is attributable to improper feed, management, sanitation programs as well as inbreeding within flocks (Jaturasitha et al., 2002). The review of Choprakarn and Wongpichet (2007) reported that the desired weight of live native birds for consumption ranged 1.0-1.5 kg. The heavier size the birds reflected the longer period of rearing that may result to tougher meat texture (Choprakarn & Wongpichet, 2007).

In Chiang Mai province, the large-scale poultry meat production is aimed to serve the demands of high quality of meat. Distribution of those meat products is still mainly focused on urban fresh markets, their companies' shops and other places such as restaurants, hospitals and hotels. Commercial slaughterhouses were not fully achieved the GMP standard because of some mismatched slaughterhouse structures that required a large budget to improve or renovate those structures. So, the poultry meat products sold in supermarkets were still from the Central part where there are industrial integrated and commercial production systems with high level of biosecurity to achieve the exportation regulations and GMP standards.

The meat products from backyard slaughterhouses were sold in village markets. Generally, the price of chickens sold by backyard slaughterhouses was higher than the commercial type because the breed of the chickens that was a native breed rearing in a free-range system. So, it required a longer rearing period than the commercial system. Most of native chickens raised in rural areas were belong to smallholders while some of those were semi-intensively raised to supplement the income of farmers. The native chickens in some areas are commercially raised to serve niche markets (Choprakarn & Wongpichet, 2007). Besides low-fat meat preference of consumers (Jaturasitha et al., 2002), even higher price of chicken meat, people still purchase native chicken meat because it is a protein source that they can access in their living areas (Kryger et al., 2010). Moreover, native chickens are also supplied in special occasions such as Chinese New Year's Day and the price is at least twice of the normal price. Price of native chicken carcass is higher than the price of broiler carcass when measured in terms of weight, corresponding to the review of Kryger et al. (2010). The price of the native chicken meat, mostly based on satisfaction of the sellers (slaughterhouse owners) that either arbitrary sell for whole carcass or by weight of the chickens. The price range between 100 - 140 THB per kilogram or per carcass compared to the commercial breed 60 - 74 THB per kilogram of whole carcass (data from June 2016 to May 2017) (KasetPrice, 2017).

5.1.2 Type of samples used in the study

Whole carcass samples is normally used in quantitative studies performed with a carcass rinsing technique. The carcass rinsing technique was also performed in studies that aimed at detection and quantification purposes at the same time (Botteldoorn et al., 2008; Toplak, Kovač, Piskernik, Možina, & Jeršek, 2012; Ivanova et al., 2014). In this study, whole carcass rinsing was used to enumerate number of *C. jejuni* contaminated on chicken carcasses as the main objective of the study besides reporting the contamination rate. The purpose of using carcass rinsing technique was to represent level of contamination of whole carcass that people supposed to get when they consume chicken meat.

In addition, studies of *Campylobacter* prevalence in slaughterhouses generally used cecum or cloacal swab samples to assess prevalence of *Campylobacter* that primarily inhabits in the intestinal tract of chickens (Padungtod & Kaneene, 2005; Hue et al., 2010; Mäesaar et al., 2014; Torralbo et al., 2015; Han et al., 2016). Neck skin samples and carcass surface swab also used to detect *Campylobacter* in order to represent the area that most likely to contaminate with intestinal bacteria when pass slaughter process (Padungtod & Kaneene, 2005; Chokboonmongkol et al., 2013; Wieczorek & Osek, 2015).

5.1.3 Contamination rate of *Campylobacter jejuni* in poultry carcasses

Studies of *Campylobacter* in poultry slaughterhouses in Chiang Mai were primarily focused on the detection *Campylobacter* spp. less specifically to *jejuni* species (Padungtod & Kaneene, 2005; Chokboonmongkol et al., 2013). This study was the first report represented the detection of *Campylobacter jejuni* in different slaughterhouse settings, backyard and commercial plants, in Chiang Mai province. The presence of *Campylobacter jejuni*-positive samples from backyard slaughterhouses was significantly 1.6 times higher than that observed in commercial slaughterhouses (contamination rate 91% compared to 57%, $p<0.05$). Contamination of *Campylobacter* on broiler carcasses was found in all slaughterhouses and the average contamination rate of each type of slaughterhouses was highly observed than the previous studies of Padungtod and Kaneene, 2005 (38% of surface swab samples) and Chokboonmongkol et al. (2013) (51% of broiler skin samples) in Chiang Mai area. Contamination rates in commercial slaughterhouses were various between countries. The prevalence of *C. jejuni* in Malaysia was 43.3% (Rejab et al., 2012) whilst in China, Poland, Brazil and Spain were 24.6%, 27.2%, 36.2% and 28.5%, respectively (Han et al., 2016; Wieczorek & Osek, 2015; Perdoncini et al., 2015; Torralbo et al., 2015).

Colonization of *C. jejuni* in chickens' intestinal tract (cecal samples) was significantly higher in the backyard when compared to commercial plants (2.8 times). High prevalence of *Campylobacter* can be found in domestic backyard flocks. The study of prevalence and genetic diversity of *Campylobacter* spp. in domestic backyard poultry in Canterbury, New Zealand reported that 86% of domestic backyard chicken flocks tested positive for *Campylobacter* spp. (57% *C. jejuni* positives, 6% *C. coli* positives and 23% both *C. jejuni* and *C. coli* positives) (Anderson, Horn, & Gilpin, 2012). Free-range system and time of raising suggested to be factors that result to high prevalence of *Campylobacter*-positive flocks of native birds rather than captive birds raised in commercial farms. A study of *Campylobacter* in free-range breeder flock found that the prevalence at five weeks of age was 20% and a peak of prevalence occurred between 10 and 13 weeks of age with the highest prevalence of 88% occurred at 11 weeks (77 days) of age (Colles, McCarthy, Layton, & Maiden, 2011). The study reported that there was no correlation between prevalence of *Campylobacter* colonization in a single free-range broiler breeder flock and season, temperature, the amount of rain and sunshine, or the dynamics of colonization among geographically and temporally matched broiler flocks (Colles et al., 2011).

Free-range or less controlled rearing of domestic chickens in rural areas influenced chickens to expose to multiple sources of *Campylobacter* in environmental reservoirs, including other farm or wild animals, water sources and soil (Anderson et al., 2012). The study of Rivoal shown that soil was the source of *Campylobacter* colonization due to the strain found in *Campylobacter*-free chickens was the same strain isolated from soil after they exposed to open area (Rivoal, Ragimbeau, Salvat, Colin, & Ermel, 2005). Moreover, biosecurity measures and hygienic practices applied to commercial farms, such as the use of overshoes, boot dip disinfectant, boot changes between different poultry houses and washing hands before and after visits, were the measures that could prevent horizontal transmission and reduce colonization of *Campylobacter* by 50% (Gibbens, Pascoe, Evans, Davies, & Sayers, 2001).

Contamination of the slaughter line caused by introduction of *Campylobacter*-positive broiler flocks to the slaughter process suggested to be one factor resulting in a high prevalence of *Campylobacter* of the consequent slaughter batches (Johannessen, Johnsen, Økland, Cudjoe, & Hofshagen, 2007; Gruntar, Biasizzo, Kušar, Pate, & Ocepek, 2015). There are studies reported that contamination of *C. jejuni* on carcass surfaces was from the strain(s) indigenous to that flock or chickens own ceca (Elvers, Morris, Newell, & Allen, 2011; Gruntar et al., 2015). Those results corresponding to the results from this study, high presence of *C. jejuni* in cecal samples (Table 4.4) from each visit tended to affect the high contamination rate of the final products. Negative cecal samples of the batches that came to slaughterhouses resulted in low contamination rate of the final products (Commercial 1#2 and Commercial 2#1), except the Commercial 2#3 that showed the high contamination rate of final products. However, limitation of this study, there were less number of samples at each step for one visit that could affect the conclusion of the contamination rate at the beginning and at the last step of sample collection.

Influence of feed and water withdrawal was the interesting factor in *C. jejuni* detection because in this study, there were the same percentage of backyard slaughterhouses that rested the chickens (with feed withdrawal) and immediately processed slaughtering after receiving of chickens. The study of Willis, Murray and Raczkowski (1996) reported that prolong of feed withdrawal time, especially if water is withheld, likely to increase the contamination rates of *C. jejuni* on the carcasses. Conversely, in this study, contamination rates of *C. jejuni* taken from backyard slaughterhouses after slaughtering were 83.3% and 100% with and without feed withdrawal, respectively.

In backyard slaughterhouses, *C. jejuni* contamination rate at slaughtering, evisceration and the final product were 91.7%, 88.9% and 91.7%, respectively. Presence of positive *C. jejuni* samples at each step was similar. The owners likely used the same areas around their houses for all slaughtering steps without low- and high-care area separation because of low production per day, which was likely to result in similar percentages of *C. jejuni* at each step. In addition, washing was not a standard operation of all backyard slaughterhouses. Immersion of carcasses in a tub after scalding and defeathering and/or evisceration was suspected to be a factor that may promote contamination from positive carcass to others.

Conversely, commercial slaughterhouses clearly separated low- and high-care areas. At evisceration, the high contamination rate was observed similarly to the study of Figueroa, Troncoso, Lopez, Rivas, and Toro (2009). Contamination of *C. jejuni* was increased 2.3 times compared with the former step of sample collection (77.8% and 33.3%, respectively). The study of Baker showed that a three to four-fold increase in carcass contamination was observed after evisceration (Baker, Paredes, & Qureshi, 1987). Evisceration suggested to be one of the slaughter steps that affects cross-contamination between carcasses because the rupture of viscera and leaking of fecal material from manual removing resulting in carcass surface and equipment contaminated with the intestinal contents (Figueroa et al., 2009; Hue et al., 2010; Gruntar et al., 2015). However, there was no carcass-rinsed samples collected before the step of evisceration, which was the limitation of this study. Comparison of the contamination rate at slaughtering and evisceration may not obviously conclude that there was significant differences since different type of samples was tested.

The commercial slaughter plants in Northern part of Thailand including Chiang Mai province generally serve demands of domestic consumption rather than exportation. Some steps, such as evisceration and carcass washing, still used manpower instead of the machine, since the improvement of infrastructure requires high investment. Even in high investment plants, rupture of the intestines and the leak of fecal content still be a problem because variation in size of carcasses may lead to improper working of the machine corresponding to the study that reported evisceration was considered to be a critical step of carcass contamination (Rosenquist, Sommer, Nielsen, & Christensen, 2006).

Additionally, the presence of *C. jejuni* on carcasses from commercial plants was decreased after washing but the difference was not statistical significant. However, the contamination rate was significantly decreased after chilling step (77.8% at evisceration compared to 50%, $p<0.05$). From a review article to evaluate the change in prevalence of *Campylobacter* on chicken carcasses during processing, most of the studies (8 out of 12) in the review showed the decrease prevalence of *Campylobacter* on chicken carcasses after chilling step. From other studies, washing and chilling are carcass processing steps that able to decrease contamination rate (Baker et al., 1987; Figueroa et al., 2009; Rejab et al., 2012). However, the study of Rejab et al. (2012) suggested that proper water volume, pressure and level of chlorine in the water were factors affected to the effectiveness of the washing step.

5.1.4 Level of *Campylobacter jejuni* contamination at each processing step

Concentration of *Campylobacter jejuni* at each processing step in this study was in the range of 2.0 - 3.8 log CFU/ml which was the concentration commonly found in other countries such as Vietnam, Madagascar, New Caledonia, and Cameroon (Garin et al., 2012). In backyard slaughterhouses, *C. jejuni* concentrations ranged 3-4 log CFU/ml which was higher than that observed from commercial plants (2-3 log CFU/ml). Counts of *C. jejuni* at each step of backyard plants were not significantly different. For the backyard type, the area in or nearby household was utilized as a processing area that usually was the combined area without zone separation of each processing step. This expected to be a reason contributed to similar counts of *C. jejuni* as shown in the results. In addition, comparison of the type of slaughterhouses, the initial concentration acquired from cecal samples was highly observed in backyard slaughterhouses (3.8 log CFU/g compared to 2.0 log CFU/g from commercial samples).

From previous studies suggested source of *Campylobacter* contaminated in chicken carcasses at slaughterhouses was predominantly occurred on farms where the pathogen colonized in the intestinal tract of chickens (Elvers et al., 2011; Gruntar et al., 2015). A study of Hue et al. (2011) reported that carcasses from batches positive with *Campylobacter* in ceca had significantly higher numbers of *Campylobacter* per gram than batches with negative ceca ($p<0.001$) corresponding to this study that carcasses from *Campylobacter*-positive batches had significantly 1.63 log CFU/ml higher than those collected from negative batches (Table 4.7).

Risk factors associated with level of *Campylobacter* colonizing among poultry flocks raised in traditional and industrialized production systems were suggested for the further study. High level of *Campylobacter* contamination in chicken carcasses from backyard plants was suggested from a source of chickens supplied to this type of slaughterhouse which was from a free-range system that chickens have long-time exposure to environments before decided to be sold for food or for income of households. In commercial type, birds are raised in closed system and rarely expose to pathogens from the environment outside housing. Raising period of commercial broiler was shorter than native chickens. Those factors may result in less exposure to *Campylobacter*. Moreover, biosecurity suggested to be a protective factor that contributed to the low level of *C. jejuni* colonization in commercial flocks.

At commercial slaughterhouses, low- and high-care areas were designed to be separated and utilized a good manufacturing practice (GMP) standard. Thus, each process was obviously separated along the slaughtering production line. The initial concentration of *C. jejuni* from carcass rinsed samples was highest at evisceration step. Study results reported by Izat, Gardner, Denton, and Golan (1988) and Seliwiorstow et al. (2016) showing that the level of *C. jejuni* was associated with evisceration operation. A study of

Rosenquist et al. (2006) observed that 0.5 log CFU/g of *Campylobacter* from neck skin samples was significantly increased, from 2 out of 4 slaughterhouse visits, after evisceration was performed (compared to after defeathering step). The higher presence of *C. jejuni* at the after evisceration step of the commercial slaughterhouse in this study similarly demonstrated that this step was the point of concern; approximately one log CFU/ml increase was observed at this step, results similar to those reported by Hue et al. (2010). Leaking of intestinal contents at this step could result to cross-contamination from intestinal to surface of carcasses.

However, lack of a former step of sample collection before evisceration was a limitation of this study since there was no prior step that used the carcass rinsing technique to compare the difference of *C. jejuni* concentration. A study of risk factors for *Campylobacter* contamination levels on broiler carcasses during the slaughter process reported that *Campylobacter* counts are influenced by the contamination of initial external carcass contamination and the colonization level of caeca (Seliwiorstow et al., 2016). Sample collection at before and after defeathering step suggested to be added for further studies for comparison of *C. jejuni* concentration in order to find out how the initial external carcass contamination associated with the concentration of *C. jejuni* contaminated in carcasses and to compare how evisceration step affect the level of contamination.

The washing and chilling steps appear to be effective measures in the poultry slaughter operations that reduced the concentration of *C. jejuni* to nearly the initial concentration. However, in this study, the results of *C. jejuni* concentration in samples from commercial slaughterhouses showed 0.33 and 0.92 log CFU/ml non-significantly decreased ($p>0.05$) after washing and chilling, respectively, when compared to evisceration step. The study of Figueroa et al. (2009) reported that approximately 1.8 log CFU/carcass of *Campylobacter* was significantly decreased from evisceration step when passed the process of chilling. Carcass washing was suggested to be added in the slaughter process of backyard slaughterhouses after evisceration to lower the number of *C. jejuni* in addition to performing the chilling alone. However, water quality is one factor to be concerned. Using chlorinated water is recommended to effectively minimize the number of the bacteria contaminated on carcasses.

The use of chlorinated water, in this study 0.5-1.0 ppm in commercial plants, during carcass washing and chilling was associated with a reduction of *Campylobacter* level on carcasses corresponding to the study of Figueroa et al. (2009). Besides, as described in the study of Rejab et al. (2012), inside-outside washing step also played a role of bacterial reduction if proper water volume and pressure were applied. However, the effectiveness of washing and chilling steps on reduction of the number of *C. jejuni* also depended on the number of *C. jejuni* colonized in the intestinal tract of chickens in positive flocks as well as the initial concentration of *C. jejuni* contaminated on carcasses at the beginning slaughter steps (Seliwiorstow et al., 2016). Limited effect of the processes on reduction of bacterial concentration may occur if the initial concentration of the bacteria is high which influence health risk to consumers (Figueroa et al., 2009).

In Thailand, there was a study on genetic relatedness of *C. jejuni* in Thai chicken production industry from entire broiler production processes started from breeder flock, hatchery, farm and slaughterhouse. The results showed that isolates from the slaughterhouse environment and meat products were similar to those isolated from broiler flocks and suggested that broilers (at farm level) were the main source of chicken meat contamination during processing (Prachantasena et al., 2016). Thus, broiler flock monitoring of *C. jejuni* at farm level may show the association between level of *C. jejuni* colonization in broiler flocks and level of *C. jejuni* contamination on chicken carcasses. *C. jejuni* found on carcass surfaces has been shown to result from horizontal (fecal) contamination of positive batches (Chokboonmongkol et al., 2013; Pacholewicz, Swart, Wagenaar, Lipman, & Havelaar, 2016; Seliwiorstow et al., 2016), which points toward the evisceration step allowing cross-contamination by chicken intestinal tract bacteria to carcass surfaces. However, in Thailand and other developing countries, routine monitoring or surveillance of *C. jejuni* of farm and slaughterhouse is not implemented.

5.1.5 Knowledge and attitudes toward meat safety

For the discussion and brainstorming sessions, participants had basic knowledge and awareness of meat safety. Contaminated poultry meat affected consumer health, quality of meat, environment, and economics. Consumption of meat products contaminated with foodborne pathogens, in participants' perspective mostly focused on bacteria, can cause foodborne illnesses. Several critical points of bacterial contamination were raised and discussed among groups. Most participants were quality control workers and plant managers. They tended to have a better understanding of the critical control points (CCP), route of contamination, health risks to consumers as well as control measures. All operation steps for the entire process of meat processing have been raised of concern, starting from transportation of chickens from farm to slaughterhouse until distribution of meat products to consumers.

Personal hygiene was less discussed among groups. Most of control measures were focused on plant facilities and good manufacturing practice (GMP) for poultry abattoir (Thailand Ministry of Agriculture and Cooperatives, 2006), based on their background. However, cleanliness and personal hygiene were the practices addressed when discussing about feasible control measures that can be actually implemented into the slaughterhouses. Addressing personal hygiene and skill training have been the difficult parts since most day labors are coming from neighboring countries or other nationalities, communication problem is one of the major barriers that affect labors' understanding. In addition, high turnover rate of employment is a burden of the slaughterhouses to train the new employed labors to have a skill of slaughtering and aware of their personal hygiene.

The study of knowledge, attitude practices regarding hygiene among abattoir workers found that there was significant correlation between practices and attitude. Workers with good attitude tend to have better practices while knowledge of the workers was not correlated to practices (Bagavandas, 2015). Thus, attitude of the workers plays an important role on hygienic practices. The laboratory results from this study, as also reported at the workshop, may help reflect the practices that affected quality of meat and help increase awareness on meat safety. However, besides attitude of the workers, education on foodborne pathogens and training on good practices are still important since those activities clarify understanding of the workers on their practices that indicate to the quality of meat.

5.2 Conclusions

Backyard and commercial slaughterhouses have totally differences in slaughter operations, but have the same purpose to serve the demands of domestic consumption. Contamination rate of *Campylobacter jejuni* in backyard processing plants was higher than that observed in commercial plants. Production system was suggested to be the main factor of *C. jejuni* colonizing in native flocks due to free-range husbandry and long raising period influenced the chickens to contact with multiple *Campylobacter* strains contaminated in environments. Moreover, sharing the same area of operations may contribute to horizontal cross-contamination of the bacteria to other carcasses resulting in high number of *C. jejuni* positive samples.

Evisceration step was suggested to be the critical point of contamination. Moreover, slaughtering of *C. jejuni* positive batches as well as *C. jejuni* that exist in slaughterhouse environment, such as on equipment and in scalding tank, were suggested to be factors that result in initial high contamination of the carcasses. However, there are other processing steps that help decrease the number of the bacteria. From the study, washing and chilling were the reduction steps of contamination that can reduce the level of *C. jejuni* approximately one log CFU/ml that closely to the initial concentration of the bacteria observed at the first step of sample collection.

Poultry meat safety was addressed to stakeholders attending the workshop. Control points of contamination and practical control measures were raised among groups after discussion and brainstorming. However, communication between the foreman and foreign day labors as well as high turnover rate of employment still be barriers that cause unstable quality of meat since language is an obstacle that affects truly understanding of the workers as well as increasing burden to the employers when the skills and personal hygiene required to be trained frequently. Investment in infrastructure, such as modern machinery, impacts the cost of production. Emphasizing hygienic practices at market level and to consumers at the last point of the food production chain were raised as the important issue in order to reduce the health risks of *Campylobacter* infection.

In conclusion, differences in contamination rate and concentration of *C. jejuni* by type of poultry slaughterhouse in Chiang Mai were reported, indicating the importance of slaughterhouse operations in reducing foodborne contamination. Skill training and personal hygiene should be emphasized to slaughter workers and managers because some slaughtering steps could promote cross-contamination along the slaughter line. However, good practices at market level and public education campaigns on proper cooking should be emphasized since control measures employed in the slaughter production line by itself was not sufficient to completely eliminate *C. jejuni* from poultry carcasses or lower the risk of foodborne diseases to consumers. Additional study to carefully identify risk factors associated with *C. jejuni* contamination in the poultry production line is needed to develop more effective interventions.