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Influence of Antemortem and Slaughtering Practices on the pH of Pork and Chicken Meats

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This study aimed to document and determine the effects of antemortem and slaughtering practices on the post-mortem pH of pork and chicken meats. Assessment of selected hog slaughterhouses (SHs) and poultry dressing plants (PDPs) located in Valenzuela City, Philippines was conducted to gather basic information regarding the practices of each plant. The post-mortem pH at 45 min and 24 h for pork (n = 39) and post-mortem pH at 20 min and 24 h for chicken (n = 24) meats produced on the visited plants were determined. Measured pH values were used as the basis for classifying meat quality as pale, soft, and exudative (PSE); dark, firm, and dry (DFD); and acceptable meat. Early post-mortem temperature was also determined in both types of meat. Ocular plant inspection revealed that the average age of pigs and chickens slaughtered were 4 mo and 40–45 d old, respectively. Animals were transported from farm to slaughterhouse in a forward open cab vehicle with a partition at a distance that ranged from 45–60 km for pigs and 65–172 km for chicken with a travel time of 1–3 h. The resting period of pigs prior to slaughter was 1.5–8 h and 2–4 h for chicken. Generally, a higher percentage of suspected DFD (38.46% *vs.* 30.30%) and PSE (17.95% *vs.* 6.06%) in pork meat was observed at early post-mortem pH in comparison to ultimate pH. The majority of the PSE-like meat came from pigs slaughtered using electric stunner while DFD incidence occurred from pigs with a short resting period prior to slaughter (1.5–2 h). For chicken meat, 29% of the samples were suspected PSE based on ultimate pH while the remaining 71% were meat with suspected acceptable quality. PSE-like meat was recorded from chicken transported from farm to abattoir with a longer travel period (3 h).

Keywords: chicken, DFD, pH, pork, PSE

INTRODUCTION

Meat quality is very important in any aspect of production. Meat sources and its production systems have a great influence on the quality of meat and the acceptability of the consumers (Toldrá 2006). PSE and DFD are two major quality defects faced by the meat industry. The undesirable appearance and texture, high potential of spoilage, limited functionality, and inferior processing yield of PSE and DFD meats continue to make these defects a critical quality and economic concern (Newton and Gill 1981; Cannon *et al.* 1996; Cassens 2000). PSE and DFD meats can be distinguished from acceptable meat quality using visual or aesthetic criteria (*i.e.*, tears, bruises, missing

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parts) or by determining the meat quality characteristics including cook loss, drip loss, color, expressible moisture, pH, and internal temperature (Owens *et al.* 2000; Barbut 2009). Meat with an acceptable quality has a drip loss of less than or equal to 5%, a hunter L* lightness score between 42–50, and an ultimate pH of less than 6.0 (Warner *et al.* 1997; Kauffman *et al.* 1998). According to Suckling (2012), these traits are considered ideal due to their positive influence on eating quality and preferable appearance as a raw meat product.

PSE and DFD conditions occur when animals are exposed to acute and chronic stresses prior to slaughter, respectively. Acute or short-term stress such as the use of electric goads, fighting among animals, and beating immediately before slaughter (Adzitey and Nurul 2011) contributed to rapid post-mortem glycolysis in meat leading to pH decline due to breakdown of glycogen to lactic acid while the carcass is still warm (Pietrzak *et al.* 1997). On the other hand, chronic or long-term stress prior to slaughter – which include long distances and long hours of transportation, food deprivation, and overcrowding of animals in the lairage – leads to the depletion of stored glycogen resulting to post-mortem low acid production and leaving the pH of meat high (Adzitey and Nurul 2011). Due to the relationship of level of animal stress prior to slaughter with the level of lactic acid production in meat, pH is one of the most commonly used parameters in determining the quality of meat in relation to PSE and DFD. Aside from stress, other factors such as genotype, the season of the year, environmental conditions, slaughtering techniques, quality of equipment, training of abattoir personnel, among others, also affect meat quality (Küchenmeister 2005; Adzitey 2011).

In many developing countries, there are laws and guidelines on animal welfare and abattoir operations but compliance is not fully enforced. This situation leads to excessive antemortem stress and poor hygiene conditions of the slaughter areas (Omotosho *et al.* 2016). In the Philippines, guidelines on good hygienic slaughtering practices (DA Administrative Order No. 19 s. 2010) and code of practice and minimum standards for the welfare of pigs (DA Administrative Order No. 41 s. 2000) are some of the few rules and regulations implemented by the National Meat Inspection Service (NMIS) of the Department of Agriculture (DA) to improve the quality of life for the animals – as well as to ensure the production of clean, safe, and wholesome meat. According to the Food and Agriculture Organization of the United Nations (FAO) (2008), a great deal of progress in the conditions of the slaughter facilities in the Philippines was observed based on the few abattoirs they visited. In spite of this, several studies have been reported that knowledge of animal welfare and its impact on meat production and quality in many developing countries are still lacking (FAO 2008; Muchenje and Ndou 2011; Asmare 2014).

This study, therefore, aimed to document the local practices in **SHs** and PDPs and to determine its influence on the pH of pork and chicken meats.

MATERIALS AND METHODS

Pre-slaughter, slaughter, and post-slaughter handling practices of four different SHs and four different PDPs were assessed in coordination with the Meat Inspection Service Office under the local government unit (LGU) of Valenzuela City. Assessment of facility and practices of the visited abattoirs was conducted based from the local standard requirements of the Philippine National Standards for Code of Hygienic Practice for Meat (PNS/BAFS 168:2015), Code of Hygienic Slaughtering Practices (DA A.O. No. 19 s. 2010), and Rules and Regulations on Humane Handling in the Slaughter of Animals for Food (DA A.O. No. 18 s. 2008). Information such as sex of animals, stocking, time and length of transportation, handling during unloading onto vehicles, duration of feed withdrawal prior to slaughter, plant design, among others, were gathered through actual observations while age and breed were provided by the supplier and the information was validated by the assigned meat inspector (veterinarian) during meat collection.

Pork and chicken carcasses were randomly selected from each of the identified SHs and PDPs to measure the temperature and pH. Pork samples were obtained from one meat dealer per SH who was willing to participate in the study. Meat dealer refers to a person or firm who rented out the facility of SH to slaughter meat food animals (DA A.O. No.5 s. 2012). The minimum number of samples was six or at least 50% of the total slaughtered animals if the throughput carcass count of the dealer was more than 12. Chicken samples (n = 6) were collected directly from the owner of the plant. The pH and temperature of pig carcasses were measured 45 min post-mortem using handheld pH-meter (pH-80, HM Digital, Inc., U.S.A.) and digital thermometer (Fisher Scientific U.K. Ltd.), respectively. On the other hand, pH and temperature measurements in chicken carcasses were done at 20 min post-mortem. Both measurements were taken at the center loin part (14th rib of the *longissimus dorsi*) of pork muscle and breast part of chicken meat and conducted at the slaughtering site. Afterwards, the pork loin and chicken breast part from the same tested carcass samples were collected, packed in a sterile polyethylene bag, placed in a cooler box containing ice (1– 4 ºC), and immediately transported within 45 min to the Food Processing Division of the Industrial Technology Development Institute in Taguig City to avoid further

contamination. At the laboratory, the samples were stored at chilling temperature (~ 4 ºC) and the ultimate pH of the meat samples was measured 24 h after slaughter using the same hand-held pH meter. Classification of meat quality as pale, soft, and exudative (PSE); dark, firm, and dry (DFD); and acceptable meat was based on the typical pH limits shown in Table 1.

RESULTS AND DISCUSSION

Ante-mortem and Slaughtering Practices of the Visited SHs

Facility. The general information on the visited hog slaughterhouses is shown in Table 2. All SHs visited were classified as "AA," which refers to SH with facilities and operational procedures sufficiently adequate to slaughter food animals or premises to cut and pack carcasses or primal parts for inter-provincial distribution and sale in any meat market nationwide (DA 2010; BAFS 2018).

The visited SHs had almost the same features and operating procedures among one another except for SH1. The distinctive characteristics of SH1 that set apart from the rest of the visited SHs were the facility, the design and construction of the plant, and the implementation of good hygienic practices. SH1 was semi-automated and semi-mechanized and was utilizing a one-level floor design for its operations. The plant was mainly composed of the following areas: receiving or off-loading, lairage, kill floor, meat inspection, area for cleaning offal, insulated rooms for chilling of meat, and adequate area for handwashing and sanitizing facilities. The photographs of the facility and operations in SH1 are shown in Figure 1.

Inside the plant, the clean and dirty areas were properly demarcated and the slaughter line was designed in a manner that the direction of operation was toward the cleaner area. The plant had elevating equipment that allows the slaughtering of pigs to be executed in a vertical position by hoisting them up on the gambrelling line. In addition, this abattoir was owned and operated by a government agency serving as a model slaughterhouse and demonstration facility where regular training was conducted for butchers and featured recommended equipment for small- to medium-scale abattoirs. SH1 allowed private entrepreneurs to rent their facility but the slaughtering activities must be conducted by the resident butchering team to maintain the hygienic practices in the plant. With the provision of enough equipment and a railing system for carcass movement, pig slaughtered in this type of facility is less exposed to stress.

The other three SHs visited were neither mechanized nor automated and slaughtering operation was carried out manually on a two-tiered floor system. In this system,

Table 1. Typical limits of pH values used for classifying PSE, acceptable, and DFD pork and poultry meats from different studies.

Meat	Condition	Main conditions describing them	References
Pork			
	PSE	$pH_{45min} < 6.0$ $pH_{24h} \leq 5.3$	Swatland 2008; Warriss 2000; Barbut *et al.* 2005
	Acceptable	pH_{45min} = 6.0–6.4; 5.8–6.0 can be considered acceptable in countries where PSE incidence is high and depending on the species	Warriss 2000; Viljoena *et al.* 2002
		pH_{24h} = 5.4–6.0; 6.0–6.2 can be considered acceptable in countries where DFD incidence is high and depending on the species	Warriss 2000
	DFD	$pH_{45min} > 6.4$	Warriss 2000; Viljoena *et al.* 2002
		$pH_{24h} > 6.2$	Bartos *et al.* 1993; Kreikemeier *et al.* 1998; Mounier *et al.* 2006
Poultry			
	PSE	$pH_{15\text{-}30mins} \leq 5.8$	Pietrzak *et al.* 1997; Ristic and Damme 2010
		$pH_{24h} \leq 5.8$	Kissel *et al.* 2009
	Acceptable	$pH_{15–30mins}$ = 5.9–6.2 $pH_{24h} > 5.8$ but < 6.3	Ristic and Damme 2010; Kissel *et al*. 2009
	DFD	$pH_{15–30mins.} > 6.3$ $pH_{24h} > 6.3$	Ristic and Damme 2010; Kissel *et al.* 2009

Table 2. General information on the visited pig slaughterhouses and the pigs for slaughter.

Checking point	Slaughterhouse			
	SH1	SH2	SH3	SH4
1. General information on slaughterhouse				
a. Meat establishment classification	AA	AA	AA	AA
b. Description of facility	Semi-automated and semi-mechanized	Traditional two-tiered floor system	Traditional two-tiered floor system	Traditional two-tiered floor system
c. Owner	Government	Private	Private	Private
d. Average number of animals slaughtered per day	6–20 pigs	300 pigs	300 pigs	30–50 pigs
e. Number of inspectors	3	2	2	2
f. Operation days per week	1	7	7	7
g. Operation hour	09:00 AM – 12:00 PM	24 h	24 h	12:00 AM – 08:00 AM
2. General information of pig for slaughter				
a. Breed	Not disclosed	Crossbreeds of Landrace × Large White	Crossbreeds of Landrace × Large White	Crossbreeds of Landrace × Large White
b. Age	4 mo	4 mo	4 mo	4 mo
c. Farm source (farm category)	Not disclosed (contracted farm)	Pandi, Bulacan (contracted farm)	Pulilan Bulacan (contracted farm)	Malinta, Valenzuela City (own farm)

Figure 1. Facility and operation at the visited semi-automated and semi-mechanized slaughterhouse (SH1): (a) receiving/off-loading area, (b) passageway to lairage area, (c) holding pen in lairage area, (d) stunning area, (e) showering of pigs, (f) driving pigs to slaughter area, (g) stunning, (h) sticking/bleeding, (i) scalding, (j) dehairing, (k) singeing, (l) evisceration, (m) splitting into half, (n) meat inspection, and (o) washing and hanging of carcass.

the killing of the pigs took place at the highest level and carcasses were gradually lowered during various procedures. This system utilizes gravity and facilitates moving the carcasses without technically complicated equipment. Photos of the facility and slaughtering operations of traditional abattoirs visited are shown in Figure 2. Most traditional pig abattoirs in the Philippines are designed using these unique features (FAO 2001). The plant composition of SH2, SH3, and SH4 was almost comparable to SH1, except that the three formerly mentioned SHs had no changing area and insulated rooms for chilling. These three abattoirs were privately-owned and facilities were rented out to meat dealers who bring in their own butchering teams. Although the three SHs were manually operated, the minimum requirements for a standard slaughter facility based on the Philippine National Standards for Code of Hygienic Practice for Meat (PNS/BAFS 168:2015) were still met as shown in Table 3, similar with SH1. In addition, despite the absence of mechanized and automated equipment, the design of these three abattoirs could still minimize the exposure of pigs to stress by using gravity to move the carcass from one place to another.

Animal source and transport. Pre-slaughter handling practices of pigs in abattoir were found to be influenced by the origin and type of pig slaughtered, the daily throughput range of pigs, and the type of abattoirs involved. All visited SHs slaughtered a mixture of breeds, but the common breed of pigs slaughtered in the three private SHs

Figure 2. Facility and operation at the visited traditional two-tiered floor system slaughterhouses (SH2, SH3, and SH4): (a) transportation vehicle of live animals, (b) receiving/ off-loading area, (c) passageway to lairage area, (d) holding pen in lairage area, (e) stunning area, (f) area for offal cleaning, (g) showering of pigs, (h) driving pigs to slaughter area, (i) stunning, (j) sticking/bleeding, (k) scalding, (l) dehairing, (m) evisceration, (n) splitting into half, (o) meat inspection, (p) washing and hanging of carcass, and (q) collection of meat carcass by meat dealers for delivery in wet market.

based on the information provided by the assigned meat inspector in each plant were crossbreeds of Landrace × Large White. The average age of pigs being slaughtered in all visited SHs was 4 mo according to the pig supplier. Pigs were commonly delivered during night time except for SH1. Delivery of pigs at night or early morning is highly recommended by Grandin (1998) because high temperature and humidity during the day are extremely dangerous for pigs, given the fact that this animal has inefficient means of respiration (Berg 2006). Grandin (1994) further suggested taking weather into account when transporting pigs to reduce PSE.

The origin of pigs in SH1 was not disclosed. Pigs in SH2 and SH3 came from a contracted farm at Pandi and Pulilan in Bulacan, respectively; while pigs in SH4 came from its own farm in Malinta, Valenzuela City. Pigs from Bulacan were transported in a forward open cab vehicle with partition and traveled at a distance ranging from 45–60 km for 1–1.5 h while pigs from Valenzuela City reached SH4 for less than 30 min. Based on the study of Warriss and colleagues (1990), pigs transported between 1–4 h has no significant effect on the ultimate pH of the meat carcass. However, pigs delivered at very short distances for under 30 min are often more stubborn and difficult to drive at the plant than pigs experiencing a longer transit time (Grandin 1994). This short duration stress may lead to a higher incidence of PSE. On the other hand, pigs transported in long distances are more likely to develop DFD meat as a result of long duration stress and depletion of intramuscular glycogen stores (Berg 2006).

According to Martoccia and co-authors (1995), pig transport was the most influential pre-slaughter factor because it affects both meat quantity and quality. However, according to Stephens and Perry (1990), researches on transportation stress are difficult to conduct because of the cumulative contribution of each component associated with transport such as the changes in velocity, vibration, handling by unfamiliar persons, mixing with unfamiliar hogs, and establishment of a new social group, among others. In general, transportation conditions will affect post-mortem meat quality by provoking stress or animal fatigue (Lambooij and van Putten 1993).

Animal handling. Assessment of pre-slaughtering practices and animal handling in the visited SHs is presented in Table 4. Hogs delivered in all SHs were fasted for 8 h prior to loading unto vehicle. According to Lee and Choi (1999), feeds withdrawal before transport is being practiced to lower pig mortality and to avoid problems at the abattoir associated with spillage of gut contents and waste disposal.

Upon arrival, pigs were driven from the off-loading area to designated holding pen in the lairage area along passageways and races. Stick and guiding boards were the guiding instruments used in SH1 while herding of pigs was achieved in the other three SHs visited by creating noise in a big plastic container. Lairage time of pigs prior to slaughter was quite different in the four SHs visited. SH1 and SH2 allowed pigs to rest for 1.5–2 h prior to slaughter while SH3 and SH4 adopted a resting period that ranged from 6–8 h (DA A.O. No.18 s. 2008). Grandin (1998) and Troeger (2003) suggested a 2–4 h lairage period for pigs to reduce the incidence of PSE meat while Honkavaara (1989) concluded in his study that the optimum range for holding pigs prior to slaughter is 3–5 h. Other works of literature reported that lairaging shorter than 1 h may increase the incidence of PSE meat while lairaging longer than 3 h may result to DFD pork and skin lesions on the carcasses (Warriss 2003; Nanni Costa

Table 3. Assessment of facility of the visited pig slaughterhouses based on local standard requirements[a,b,c].

Facilities of slaughterhouse	Slaughterhouse			
	SH1	SH2	SH3	SH4
1. ***Receiving area***				
• Has offloading platforms	✓	✓	✓	✓
2. ***Animal holding area***				
• Near the slaughter hall but not located within	✓	✓	✓	✓
• Feeding and watering troughs for each pen	✓	✓	✓	✓
• Well-ventilated (with open space between the wall and the roof)	✓	✓	✓	✓
• Non-slip floor	✓	✓	✓	✓
• Clean and adequate drinking water provided	✓	✓	✓	✓
• Ramps, weighing scale, and showers installed	✓	✓	✓	✓
• Lighting strategically located to encourage animals to move forward	✓	✓	✓	✓
3. ***Slaughter area***				
• Direction of the operation toward the cleaner area	✓	✓	✓	✓
• Separate area for condemned parts and provisions for its quick removal	✓	×	×	×
• Separate rooms used for emptying and cleaning alimentary tracts	✓	✓	✓	✓
• Proper and functional drainage and waste disposal system	✓	✓	✓	✓
• Adequate handwashing and sanitizing facilities	✓	×	×	×
• Adequate ventilation to prevent excessive heat, humidity, and condensation	✓	×	✓	✓

[a]Code of Hygienic Practice for Meat (PNS/BAFS 168:2015)
[b]Guidelines on Good Hygienic Slaughtering Practices for Locally Registered Meat Establishments (DA A.O. No. 19 s. 2010)
[c]Rules and Regulations on Humane Handling in the Slaughter of Animals for Food (DA A.O. No.18 s. 2008)
✓ compliant; ×non-compliant

Table 4. Assessment of pre-slaughtering practices of the visited pig slaughterhouses based on local standard requirements[a,b,c].

Checking point	Slaughterhouse			
	SH1	SH2	SH3	SH4
1. ***Transportation of animals for slaughter***				
• Transport vehicles allow easy loading and unloading	✓	✓	✓	✓
• Transport vehicles equipped with floors that provide secure footing	✓	✓	✓	✓
• Transport vehicles with partition	✓	✓	✓	✓
• Pigs able to lie down and stand-up in their natural position	✓	✓	✓	✓
• Animals transported during the coolest part of the day	×	✓	✓	✓
• Travel time (< 12 h)	✓ (not disclosed)	✓ (1–1.5 h)	✓ (1 h)	✓ (< 30 min)
• Feed withdrawal prior to transport (8 h)	✓ (8 h)	✓ (8 h)	✓ (8 h)	✓ (8 h)
2. ***Receiving of animals for slaughter and lairage***				
• Accompanied by documents required by competent authorities	✓	✓	✓	✓
• Have proper identification	✓	✓	✓	✓
• Healthy and clean	✓	✓	✓	✓
• Underwent antemortem inspection	✓	✓	✓	✓
• Unloading and moving of animals done with minimum stress	✓	✓	✓	✓
• Allowable instruments for moving animals used	✓ (guiding boards used for blocking)	✓ (herding of pigs achieved through the noise created by large plastic container)	✓ (same with SH2)	✓ (same with SH2)
• Animals within the establishment not subjected to inhumane acts (*e.g.*, kicking; ear and tail twisting; eye, genital, and anal poking, *etc.*)	✓	✓	✓	✓
• Lairage time (6–12 h)	× (1.5–2 h)	× (1.5–2 h)	✓ (6–8 h)	✓ (6–8 h)
• Lairage area provide enough space for each animal to lie down and turn around	✓	✓	✓	✓

[a]Code of Hygienic Practice for Meat (PNS/BAFS 168:2015)
[b]Guidelines on Good Hygienic Slaughtering Practices for Locally Registered Meat Establishments (DA A.O. No. 19 s. 2010)
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et al. 2002). Aside from holding period, the following lairage conditions were also observed in all of the SHs visited: group penning, providing enough space to each animal to lie down and turn around, sprinkling of water, and provision of drinking water. These practices were also proven to avoid stress in animals (Troeger 2003). After holding for a few hours, pigs were driven from lairage to stunning area along passageways in a similar manner during unloading of pigs to the lairage area. Showering of pigs prior to stunning was being practiced in all of the visited SHs. According to Muchenje and Ndou (2011), the showering of pigs can reduce the incidence of PSE of meat under harsh weather. Klont and Lambooy (1995) further explained that the showering of pigs will lower the muscle temperature prior to exsanguination. This will allow body temperature to be more close to "normal" during early post-mortem metabolism conversion of muscle to meat.

Slaughtering practices. The summary of the slaughtering practices of the visited slaughterhouses is shown in Table 5. In all but one of the abattoirs, stunning of pigs was done by blowing the skull with a metal bat. It requires manual force and a well-trained person to ensure that pigs are hit properly and unconscious prior to sticking and bleeding (FAO 2001). Only SH1 was using a hand-held V design tong-type electrode for stunning, which was applied to each side of the head below the ear of the pig. The

Table 5. Assessment of slaughtering and post slaughtering practices of the visited pig slaughterhouses based on local standard requirements[a,b,c].

Checking point	Slaughterhouse			
	SH1	SH2	SH3	SH4
1. ***Slaughter practices***				
• Showering				
- Conducted before entering the slaughterhouse	✓	✓	✓	✓
• Stunning				
- Performed with the use of a device which effectively renders the animal insensible to pain	✓ (electric stunner)	✓ (metal bat)	✓ (metal bat)	✓ (metal bat)
- Stunning to sticking interval (max. of 15 s)	✓	✓	✓	✓
- Stunning device operator has the expertise to ensure effective stunning with minimum stress of the animal	✓	✓	✓	✓
• Sticking and bleeding				
- Carried out on animals that had been stunned	✓	✓	✓	✓
- Completely bled before further dressing procedure carried out	✓ (5–7 min)	✓ (2–5 min)	✓ (2–5 min)	✓ (2–5 min)
• Scalding				
- Approximately 60 ºC	✓ (60–62 °C for not more than 6 min)	✓ (60 °C and above for approx. 5 min)	✓ (same with SH2)	✓ (same with SH2)
- Potable water used	✓	✓	✓	✓
- Regularly changed before each operation	✓	×	×	×
• Dehairing				
- Done off-floor and/or slatted dehairing tables	✓ (using dehairing machine)	✓ (manual)	✓ (manual)	✓ (manual)
• Evisceration				
- Prevent accidental cuts and leaks of intestinal contents	✓	✓	✓	✓
• Carcass splitting				
- Done while hanging on rail or on top of clean surfaces	✓ (using mechanical saw while hanging on rail)	✓ (using large knife lain horizontally on table)	✓ (same with SH2)	✓ (same with SH2)
• Final trimming and washing of carcass				
- Done to remove damaged, soiled, unwanted tissues and remaining blood on cut surfaces	✓	✓	✓	✓
2. ***Post-slaughter practices***				
• Post-mortem inspection				
- Performed without delay after slaughter of animals	✓ (carcass by carcass)	✓ (randomly)	✓ (randomly)	✓ (randomly)

[a]Code of Hygienic Practice for Meat (PNS/BAFS 168:2015)
[b]Guidelines on Good Hygienic Slaughtering Practices for Locally Registered Meat Establishments (DA A.O. No. 19 s. 2010)
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✓ compliant; ×non-compliant

stun duration varied according to the weight of pigs and ranged between 2–15 s. Both stunning techniques have a detrimental effect on the quality of meat if not properly executed. Stunning using a metal bat, since manually conducted by a butcher, is prone to inadequate stunning wherein additional blows in the animal is applied to make the pig unconscious. In the worst case, pigs were still conscious during sticking and bleeding. On the other hand, stunning pigs with high voltages or currents may result in bone fractures and blood splash (Gregory 1987). Aside from bone fracture and blood splash, other meat quality defects caused by inadequate stunning are bruising, insufficient bleeding, and PSE meat (Berg 2006).

Slaughtering practices of SH1 were different from the rest of the SHs visited. This might be due to the fact that SH1 has a better facility and well-trained personnel. In SH1, stunned animals were positioned immediately for bleeding. It was done by hanging the pigs in a vertical position through shackling one hind leg and hoisting the animal to a convenient height. Bleeding of the animal either in vertical or horizontal positions is both acceptable but slaughtering the animal in vertical position has an advantage of avoiding microbial contamination (Troeger 2003).

The bleeding operation in SH1 was properly done by sticking a small hole through the neck, severing the carotid arteries and jugular vein. Animals were then allowed to bleed out for 5–7 min. Blood was collected in a large receptacle. After bleeding, pigs were scalded one at a time in a scalding vat with a temperature of 60–62 °C for not more than 6 min. Scalding water was clear and replaced from time to time. Pigs were then dehaired using a dehairing machine. Further removal of hair was done by singeing the carcass with a handheld torch. Aside from reducing hair stubble, singeing can also reduce the microbial count by 1–2 logs (Troeger 2003; ICMSF 2005). The carcasses in SH1 were eviscerated and split into half by means of mechanical splitting saw while the carcass was hanging in rails in a vertical (head down) and spread position. The viscera were removed with caution and transferred to a room for cleaning the offals. The inspection of each carcass and its internal organs was being done by a meat inspector. Meat parts or carcasses that did not pass the requirement as edible meat were being condemned. After removal of viscera and passing the inspection, carcasses were being washed, weighed, and chilled.

Slaughtering practices of the other three SHs were almost similar, which may be attributed to the common two-tiered floor design of the three facilities. All slaughtering activities were performed with the carcass lain horizontally. Bleeding of animals was done immediately after stunning by sticking the knife in the neck. Blood was collected in a container that was held close to the bleeding wound. Bleeding time ranged from 2–5 min. Slaughtered pigs were then scalded in a scalding vat by batch at 60 °C and above for approximately 5 min. A lot of hogs were scalded in the same hot water resulting in rapid pollution of the scalding water. This practice may pose a risk of microbial internal contamination of the lung, liver, heart, and muscles (Troeger 2003). Carcasses were dehaired manually using a knife in a scraping table. Singeing was not being practiced in the three SHs. The opening and evisceration of carcasses were also done in the same scraping table using a large knife. Although there is no floor contact and this process is still considered acceptable, equipping the abattoir with sufficient overhead rails that enable evisceration and splitting each carcass in a vertical position is suggested by the FAO (2001) to avoid possible contamination of meat from performing the dehairing, evisceration, and splitting on the same working surface. After evisceration, the viscera were transferred in a separate room for cleaning. Carcasses were then hung in rails in a vertical position for washing and air-drying. Meat inspection was also done but not as thorough as in SH1, which might be due to the large volume of carcasses. After hanging in rails for not more than 2 h at ambient temperature, the carcasses were collected by meat dealers and distributed to wet markets within Valenzuela City and in other neighboring towns. Delivery vehicles used for transport of meat to markets were enclosed modified trucks that allow the hanging of carcass parts.

In general, SH1 was the most hygienically satisfactory facility among all the abattoirs visited. Other abattoirs need further improvements specifically on the stunning, scalding, and evisceration procedures. Upgrading of stunning tools is necessary to avoid slaughtering conscious animals, which is against the animal welfare and may cause negative impacts on meat quality. Monitoring of scalding temperature and frequent renewal of the water used for scalding are also highly recommended to avoid microbial contaminations. SHs are also encouraged to equip the facility with a railing system to allow eviscerating and splitting of each carcass in a vertical position. It is also evident that government and relevant stakeholder interventions are necessary for the area of personnel training on best practices to ensure the wholesomeness of meat products and the protection of public health.

Quality of Pork Meat Produced in the Visited Slaughterhouses

Pork quality traits according to post-mortem pH and temperature were investigated from 39 pigs of the visited SHs in Valenzuela City, as shown in Table 6. Samples collected from SH1, SH2, and SH3 have a higher number of female pigs than male pigs while equal numbers of male and female pig samples were examined in SH4. The internal temperature of pork loin meat at 45 min

Table 6. Quality of pork meat samples obtained from the visited slaughterhouses.

Quality traits	Slaughterhouse				All SHs (n = 39)
	SH1 (n = 6)	SH2 (n = 15)	SH3 (n = 12)	SH4 (n = 6)	
Gender					
No. of males	1	5	5	3	**14**
No. of females	5	10	7	3	**25**
$Temp._{45min}$ (C)*	40.07 ± 0.72	38.80 ± 1.31	38.35 ± 1.74	38.26 ± 1.25	**38.83 ± 1.45**
Post-mortem pH					
pH_{45min}*	5.45 ± 0.33	6.52 ± 0.29	6.31 ± 0.24	6.16 ± 0.26	**6.24 ± 0.45**
pH_{24h}*	ND**	6.15 ± 0.26	6.03 ± 0.23	5.79 ± 0.42	**6.04 ± 0.30**
Classification based on pH_{45h} post mortem					
Suspected PSE – count (%)	5 (83.33)	0 (0)	0 (0)	2 (33.33)	**7 (17.95)**
Suspected DFD – count (%)	0	10 (66.67	3 (25)	2 (33.33)	**15 (38.46)**
Suspected meat with acceptable quality – count (%)	1 (16.67)	5 (33.33)	9 (75)	2 (33.33)	**17 (43.59)**
Classification based on pH_{24h} post mortem					
Suspected PSE – count (%)	ND**	0 (0)	0 (0)	2 (33.33)	**2 (6.06)**
Suspected DFD – count (%)	ND**	7 (46.67)	2 (16.67)	1 (16.67)	**10 (30.30)**
Suspected meat with acceptable quality – count (%)	ND**	8 (53.33)	10 (83.33)	3 (50)	**21 (63.64)**

*Mean ± standard deviation
**Not determined because the slaughterhouse did not approve the request

after the slaughter was measured. The highest average temperature of 40.0 ±. 07 °C was recorded in carcasses from SH1. Slightly close average meat temperature values were recorded from SH2, SH3, and SH4 – which were 38.80 ± 1.31 °C, 38.35 ± 1.74 °C, and 38.26 ± 1.25 °C, respectively. The high-temperature value of pork temperature at SH1 might be attributed to the time of slaughtering operation. As shown in Table 2, slaughtering operation in SH1 happened between late in the morning going noontime. Therefore, the initial temperature of the pork samples at 45 min post-mortem was measured where the environmental temperature was at its peak. On the other hand, bulk production of the other three SHs happened during the night whereas sampling of carcasses was done between 01:00 – 03:00 in the morning where the environmental temperature was lower compared to SH1. Another possibility would be the effect of singeing as SH1 was the only abattoir that used this step among SHs visited. In the study of Maribo and his colleagues (1998), a 1 °C increase in the temperature of scalded and singed carcasses was recorded in comparison with dehided carcasses that did not undergo singeing.

Post-mortem pH at 45 min of pork samples was also measured. Meat samples from SH1 had the lowest average $pH_{45\ min}$ of 5.45 ± 0.33 followed by SH4, SH3, and SH2 with average values of 6.16 ± 0.26, 6.31 ± 0.24, and 6.52 ± 0.29, respectively. According to literature, meats with post-mortem pH at 45 min lower than 6.0 are considered PSE (Warriss 2000; Barbut *et al.* 2005; Swatland 2008) while meats with pH of 6.4 and above are DFD (Warriss 2000; Viljoena *et al.* 2002). This indicated that meat samples from SH1 and SH2 were suspected PSE and DFD meats, respectively.

It was observed during the ocular inspection that the best practices for animal handling and slaughtering were done in SH1. However, the post-mortem pH value of the meat samples from the said abattoir still falls under the category of PSE (83.33%). The low pH value of meat from SH1 might be associated with the stunning system of the plant. Among all the visited SHs, only SH1 was using an electrical stunner. According to Petersen and Blackmore (1982), head-only electrical stunning of the animal may lead to a serious physical post stunning convulsion and can increase the rate of the post-mortem muscle glycolysis due to increase muscular activity and elevated cathecolamines into the blood. Some studies pointed out the common problems associated with electrically stunned pigs including a sharp decrease in the muscle pH, blood splash, and PSE meat incidence (Barton-Gade *et al.* 1992; Raj *et al.* 1997; Faucitano *et al.* 1998). The low initial pH of meat samples from SH1 might be compensated by the chilling system of the plant.

In the case of SH2, the high pH value of meat samples was not yet clear since almost all the handling practices and slaughtering activities of SH2 were similar to SH3 and SH4. In fact, most of the slaughtering activities in SH2 were expected to be more prone to producing PSE meat than DFD meat because the lairage time was shorter compared to SH3 and SH4 and the environmental temperature of SH2 was higher compared to other abattoirs due to heat produced from the open fire for heating the scalding vat inside the plant. In the study of Guàrdia and co-authors (2005), gender influenced the risk of obtaining DFD pork. The study reported that females had a tendency of producing DFD meat than males. The said report was in accordance with the findings of Van der

Wal and co-authors (1999), indicating that males either have more energy reserves in their muscles and their energetic metabolism is slightly different from females. The study further discussed that males were more used to chronic stress because of their more aggressive sexual behavior. With these, the high number of suspected DFD (66.67%) of the present study may be associated with gender since the large part of the population in SH2 is female (10 out of 15), as shown in Table 6.

While it has been suggested in several works of literature that the pH measured at 45 min post-mortem can be used to predict pork quality, results from the study of Boler and colleagues (2009) demonstrated that pH of pork at 24 h post-mortem is the best pH time point to predict pork quality traits. The said study showed that the pH of pork at 24 h post-mortem had a higher correlation to pork quality traits such as color, firmness, marbling, % purge loss, and % cooking loss than in pH measured at 45 min post-mortem. The pH of meat at 24 h is also known as the ultimate pH (Baeâza 2004).

In the present study, pH_{24h} of pork samples from SH1 was not determined because the meat dealer or the owner of meat carcasses decline to further participate in the study. The average ultimate pH of meat samples from the three remaining SHs was 6.15 ± 0.26, 6.03 ± 0.23, and 5.79 ± 0.42 for SH2, SH3, and SH4, respectively. Among the three remaining SHs, only SH4 was recorded to have suspected PSE (33.33%) from meat samples collected based on the ultimate pH. The occurrence of suspected PSE on SH4 can be attributed to the short transport distance of the meat since pigs came from the farm within Valenzuela City. This result is in accordance with the observation of Grandin (1994) wherein pigs hauled at very short distances for under 30 min are often difficult to handle and drive at the plant, leading to a higher incidence of PSE. Similarly, Tarrant (1989) supported this argument suggesting that shorter transport time may be more detrimental than longer ones because the largest increase in heart rate occurred immediately on starting the engine (to generate vibration and noise) and then gradually declined as the transport progressed (Stephens and Perry 1990). SH2 and SH3 have no suspected PSE meat but SH2 had the highest percentage of suspected DFD meat (46.67%), consistent with the previous findings at early post-mortem pH. Both SH3 and SH4 had 16.67% of suspected DFD samples. Among the four abattoirs visited, SH3 had the highest percentage of meat samples with suspected acceptable quality at 83.33%. It was followed by SH2 and SH4 with 53.33% and 50.00%, respectively. It was also observed that lower suspected DFD and PSE meats were recorded during 24 h post-mortem than during 45 min post-mortem. This indicates the importance of post-slaughter practices (*e.g.*, chilling) aside from antemortem practices.

Ante-mortem and Slaughtering Practices of the Visited PDPs

Facility. The summary of information on the visited PDPs is shown in Table 7. All PDPs visited were classified as "locally registered meat establishments." This type of meat establishment is recognized and allowed to operate by the LGU but are not accredited by the NMIS (DA 2012). The distribution and sale of meat and meat products are only limited to the city/municipality where the meat establishment is located (HLURB 2015).

The design and facilities available in the four PDPs were almost similar and support manual method of slaughtering. The plants were lacking in standard slaughter facilities and basic amenities based on the minimum requirements described in the PNS for Code of Hygienic Practice for Meat (PNS/BAFS 168:2015), as shown in Table 8. Three out of the four PDPs were located in the wet market area. PDP1 and PDP2 were both physically connected to their meat stalls at a wet market while the PDP3 facility

Table 7. General Information on the visited poultry dressing plants and the chicken for slaughter.

Checking point	Slaughterhouse			
	PDP1	PDP2	PDP3	PDP4
1. General information on slaughterhouse				
a. Meat establishment classification	LGU registered	LGU registered	LGU registered	LGU registered
b. Location	Located in wet market	Located in wet market	Located in wet market	Located in residential area
c. Owner	Private	Private	Private	Private
d. Average number of animals slaughtered per day	100–300	100–300	100–300	100–300
e. Number of inspectors	1	1	1	1
f. Operation days per week	7	7	7	7
2. General information of animal for slaughter				
a. Age	4 mo	4 mo	4 mo	4 mo
b. Farm source (farm category)	Not disclosed (contracted farm)	Pandi, Bulacan (contracted farm)	Pulilan Bulacan (contracted farm)	Malinta, Valenzuela City (own farm)

Table 8. Assessment of facility of the visited poultry dressing plants based from local standard requirements[a,b,c].

Facilities	Slaughterhouse			
	PDP1	PDP2	PDP3	PDP4
1. ***Animal holding area***				
• Near the slaughtering area but not located within	×	×	×	×
• Well-ventilated	×	×	✓	✓
2. ***Slaughter area***				
• Kill floor area with physical separation or barrier from dressing area	×	✓	×	×
• Direction of the operation toward the cleaner area	✓	✓	✓	✓
• Separate area for condemned parts and provisions for its quick removal	×	×	×	×
• Separate rooms used for emptying and cleaning alimentary tracts	×	×	×	×
• Proper and functional drainage and waste disposal system	✓	✓	✓	✓
• Adequate handwashing and sanitizing facilities	×	×	×	×
• Adequate ventilation to prevent excessive heat, humidity, and condensation	×	×	✓	✓

[a]Code of Hygienic Practice for Meat (PNS/BAFS 168:2015)
[b]Guidelines on Good Hygienic Slaughtering Practices for Locally Registered Meat Establishments (DA A.O. No. 19 s. 2010)
[c]Rules and Regulations on Humane Handling in the Slaughter of Animals for Food (DA A.O. No.18 s. 2008)
✓ compliant; × non-compliant

was not connected to its meat stall but had very close proximity to it (approximately 100 m). According to FAO (1992), slaughtering of poultry near the market area may be considered reasonable – especially if a small number of birds are to be slaughtered – since the market requires fresh and unchilled meat. On the other hand, PDP4 was far from the market area but was basically part of the yards of the properties where the owners reside.

The areas of the visited PDPs were not well-ventilated and very small wherein only one to two persons can work inside the plant, except for PDP4 where it can accommodate at least five workers. The facilities of the four PDPs were mainly composed of receiving and holding area of live chickens and kill floor areas where sticking, bleeding, scalding, and defeathering were performed, as shown in Figure 3. The areas were poorly demarcated as its holding accommodations of live chickens awaiting slaughter have no physical separation or barrier from slaughtering activities. Only PDP2 had a separate small room for scalding and defeathering. Evisceration was commonly conducted in their display area in the wet market before market opening hours. The establishments did not have appropriate personal hygiene facilities, hand washing and drying area, and appropriate protective clothing for the personnel or workers. The main equipment available in the four PDPs was the scalding vat and the defeathering machine. With the design of the facility discussed above, a high probability of animals was exposed to stress prior to slaughter. This would greatly affect the quality of meat produced (Adzitey and Nurul 2011).

Animal sources. The chickens in PDP1, PDP2, and PDP3 came from a contracted farm in San Miguel, Bulacan while the chicken supplies in PDP4 originated from a contracted farm in Bagac, Bataan. The distance of the farm to PDP ranged from 65–172 km. The average travel time from farm to PDPs was 2.5 h. The transport time was within the acceptable level of < 4 h (Vieira *et al.* 2011). One of the important factors that affect the quality of chicken meat is the condition during transport of live animals (Mitchell and Kettewell 1998; Langer *et al*. 2010; Simões *et al*. 2009a, b). Transportation systems of the live chickens of the four PDPs were similar. Chickens were transported in an open cab vehicle with cage partition. The capacity of the vehicle was 1000 heads and 20 heads per cage. The daily average delivery of live chickens in each PDP ranged from 100–300 with an average weight of 1.8–2.0 kg. Based on the information provided by the suppliers, the age of the delivered chickens in the four PDPs ranged from 40–45 d. The information provided was validated by the veterinarian who inspected live chickens upon receipt.

Pre-slaughter practices. The summary of pre-slaughter practices is shown in Table 9. The pre-slaughter practices observed in PDPs included transportation, unloading of animals, and lairaging. Delivery of live chickens was done early in the morning. This is ideal to avoid the incidence of PSE brought by high environmental temperature during day time (Mir *et al.* 2017). Upon arrival, live chickens stayed on the delivery trucks for 1–2 h until the opening hours of PDPs. Manual and by batch transferring of live chickens from the vehicle to receiving area were

Figure 3. Facility and operation at the visited poultry dressing plants (PDP1, PDP2, PDP3, and PDP4): (a–b) transportation vehicle of live animals and unloading of chicken, (c–d) transfer of chickens from vehicle to holding area, (e–g) holding area, (h–k) slaughtering area, (l–m) sticking and bleeding, (n–p) scalding, (q–s) defeathering, and (t–u) evisceration.

being practiced by PDPs. It was done by the delivery man lugging about 10–20 chickens hanging in vertical positions (heads down) from both ends of long bamboo poles or stick carried on their shoulders. Only PDP2 was using a cart for transferring the chickens, as shown in Figure 3c.

The most critical stress-inducing stages in the slaughtering of poultry, according to Mir and his colleagues (2017), are the unloading, shackling, and stunning of birds. With the observation of the unloading system of the present study, a high level of stress can be experienced by the live chickens. Raj and his co-authors (1997) suggested automatic unloading of crates in the slaughterhouse in order to improve and make this process less stressful. However, given that the PDPs in Metro Manila are only micro-scale and have little capital, using simple techniques to lessen the stress of animals such as using suitable carts to transfer chickens – like what was done by PDP2 – is already enough and appropriate.

The delivered chickens were allowed to rest in the holding accommodation area inside the plants from 2–4 h before being slaughtered. According to delivery men, chickens have been withdrawn from water and feed for 8 h from the farm. Several authors have recommended less than 2 h lairage time for poultry because of the low energy available in fasted, metabolically active birds (Hunter 1998; Warriss *et al.* 1999; Nijdam *et al.* 2004). However, Vieira and co-authors (2011) suggested that lairage time of 3–4 h is necessary for tropical regions during the summer season to reduce the thermal load of chickens.

Slaughtering practices. The slaughter processes observed in all PDPs included bleeding, scalding, defeathering, evisceration, and distribution of chicken meat. The summary of the assessment is provided in Table 10 and illustrated in Figure 3.

All visited PDPs were not practicing stunning. In most countries, the stunning of animals for slaughter is a legal requirement, where the animals for meat consumption should instantaneously be rendered insensible and remain insensitive to pain until the brain is completely unresponsive (Council Directive 93/119/ CEE, 1993). In the study of Kissel and colleagues (2015), a high incidence of PSE (54.14%) was recorded in poultry meat slaughtered without stunning. It was reduced to 25% when the meat samples were slaughtered with stunning.

Bleeding of chicken from the four PDPs was done by sticking the neck of the chicken using a sharp knife immediately after leaving the cage in the holding area. Bleeding was done for less than a minute and blood was collected in a small basin. All slaughtered chickens were collected in one container before being scalded. The scalding process was done by immersing 5–10 carcasses in a scalding vat containing water heated at 60–65 °C over a gas stove or firewood for 2–3 min. These practices followed the recommended bleeding time and scalding temperature by the NMIS (2013). The scalded carcasses were then moved from the bath to a spinning defeathering machine with a capacity of 5–10 chickens.

Re-scalding of the defeathered chickens was being practiced in the three PDPs, except in PDP4. Instead, washing the carcasses with potable water was done in PDP4 after defeathering and prior to carcass distribution. Because of limited space, evisceration was commonly done in the display area in the wet market where tables were available. The head, feet, and intestines were removed. Viscera were collected in a plastic bag and transferred to certain butchers who are specialized in

Table 9. Assessment of preslaughter of the visited poultry dressing plants based on local standard requirements[a,b,c].

Checking Point	Slaughterhouse			
	PDP1	PDP2	PDP3	PDP4
1. ***Transportation of animals for slaughter***				
• Transport vehicles allow easy loading and unloading	✓	✓	✓	✓
• Transport vehicles with partition/cages	✓	✓	✓	✓
• Cages in transport vehicle with appropriate space allowance and ventilation	✓	✓	✓	✓
• Animals transported during the coolest part of the day	✓	✓	✓	✓
• Travel time (< 12 h)	✓ (2 h)	✓ (2 h)	✓ (2 h)	✓ (3 h)
• Feed withdrawal prior to transport (6–8 h)	✓ (8 h)	✓ (8 h)	✓ (8 h)	✓ (8 h)
2. ***Receiving of animals for slaughter and lairage***				
• Accompanied by documents required by competent authorities	✓	✓	✓	✓
• Healthy and clean	✓	✓	✓	✓
• Underwent antemortem inspection	✓	✓	✓	✓
• Unloading and moving of animals done with minimum stress	× (use bamboo stick to transfer chicken by hanging in vertical position)	✓ (use cart to transfer animals from delivery van to lairage area)	× (same as PDP1)	× (same as PDP1)
• Lairage time (minimum of 2 h prior to slaughter)	✓ (2–4 h)	✓ (2–4 h)	✓ (2–4 h)	✓ (2–4 h)
• Lairage area provides enough space for each animal to lie down and turn around	✓	✓	✓	✓

[a]Code of Hygienic Practice for Meat (PNS/BAFS 168:2015)
[b]Guidelines on Good Hygienic Slaughtering Practices for Locally Registered Meat Establishments (DA A.O. No. 19 s. 2010)
[c]Rules and Regulations on Humane Handling in the Slaughter of Animals for Food (DA A.O. No.18 s. 2008)
✓ compliant; × non-compliant

Table 10. Assessment of slaughtering and post slaughtering practices of the visited poultry dressing plants based on local standard requirements[a,b,c].

Checking point	Slaughterhouse			
	PDP1	PDP2	PDP3	PDP4
1. ***Slaughter practices***				
• Stunning				
- Performed with the use of a device which effectively renders the animal insensible to pain	×	×	×	×
• Sticking and bleeding				
- Carried out on animals that had been stunned	×	×	×	×
- Completely bled before further dressing procedure is carried out	✓	✓	✓	✓
• Scalding				
- 50–80 ºC	✓ (60–65 °C for 2–3 min)	✓ (same as PDP1)	✓ (same as PDP1)	✓ (same as PDP1)
- Potable water is used	✓	✓	✓	✓
- Regularly changed before each operation	×	×	×	×
• Defeathering				
- Done off-floor	✓ (done mechanically using defeathering machine)	✓ (same as PDP1)	✓ (same as PDP1)	✓ (same as PDP1)
• Evisceration				
- Prevent accidental cuts and leaks of intestinal contents	✓	✓	✓	✓
• Final trimming and washing of carcass				
- Done to remove damaged, soiled, unwanted tissues and remaining blood on cut surfaces	✓ (rescalded)	✓ (rescalded)	✓ (rescalded)	✓ (wash with tap/potable water)
2. ***Post-slaughter practices***				
• Post-mortem inspection				
- Performed without delay after slaughter of animals	✓ (randomly)	✓ (randomly)	✓ (randomly)	✓ (randomly)

[a]Code of Hygienic Practice for Meat (PNS/BAFS 168:2015)
[b]Guidelines on Good Hygienic Slaughtering Practices for Locally Registered Meat Establishments (DA A.O. No. 19 s. 2010)
[c]Rules and Regulations on Humane Handling in the Slaughter of Animals for Food (DA A.O. No.18 s. 2008)
✓ compliant; × non-compliant

cleaning those organs. The carcasses were cut into various sizes and were set for selling and distribution. Buyers who were buying in bulk quantity were waiting in the display area before market opening to collect their orders. The number of chicken slaughtered per day in all the PDPs varied between 100–300 heads per day. It was determined by the demand as there were no functional facilities for chilling or freeze preservation of meat. The chicken meat was supplied to individual meat traders and consumers who came to PDPs and meat stalls in the market.

All the PDPs visited need a lot of improvement in terms of hygienic slaughtering practices, as well as in the design and construction of the facility. Aside from a great chance of microbial contamination due to poor demarcation of dirty and clean areas, the small space and poor ventilation inside the slaughtering plants may also result in meat quality defects due to accumulated heat. Similar to the observations in SHs, there is also an urgent need for the intervention of government and relevant stakeholders to further improve the practices of personnel and its facilities to avoid the stressing of live animals, as well as to avoid cross-contamination of meat**.**

Quality of Chicken Meat Produced in the Visited PDPs

A total of 24 chickens 40–45 d old weighing 1.8–2.0 kg on average from the four visited PDPs were investigated for the quality of the produced meat. It was done by evaluating the post-mortem temperature and pH at 20 min and the ultimate pH of the breast part of the chicken meat. Results showed that the internal temperature of chicken meat ranges from 34.83–37.38 °C, as shown in Table 11. Among the four PDPs visited, chicken meats from PDP4 had the lowest internal temperature at 34.83 ± 2.38 °C. It was followed by meat samples from PDP2, PDP3, and PDP1 with average temperatures of 36.29 ± 3.06, 37.03 ± 2.55, and 37.38 ± 0.23, respectively. The lower temperature of PDP4 in comparison with other visited PDPs may be due to the scalding technique used by dressing plants. Carcasses from the three PDPs except PDP4 were being scalded twice, which was done after bleeding and after defeathering. Another possible explanation would be the space of the slaughtering area. As mentioned in the ocular inspection at PDPs, the facility of PDP4 can accommodate at least five personnel while the other three PDPs have a very small working place where only two workers can move around the area. The insufficient space and heat accumulated from the steam during scalding would cause the area to become hot and humid. This condition could slow down the reduction of the internal temperature of rescalded carcasses from PDP1, PDP2, and PDP3.

The early post-mortem pH of chicken meat samples in the present study was recorded at 20 min. The average pH_{20min} obtained were 6.17 ± 0.16 (PDP1), 6.26 ± 0.23 (PDP2), 6.14 ± 0.16 (PDP3), and 6.05 ± 0.16 (PDP4). The values were slightly close to one another and within the suggested values for acceptable meat quality (Ristic and Damme 2010). One sample each out of the six samples from PDP2, PDP3, and PDP4 was recorded to be suspected of DFD meat at 20 min post-mortem based on pH. Although DFD in chicken is very rare, there were few researchers like Glamoclija and his colleagues (2015) who reported that DFD was found in Hubbard (50 d old) and Cobb (42 d old) broiler chickens. The authors further explained that DFD incidence in meat is dependent on the breed line and age. Unfortunately, the present study was not able to get the information on the breed line of the collected chicken samples.

Table 11. Quality of chicken meat samples obtained from the visited poultry dressing plants.

Quality traits	Poultry dressing plant				
	PDP1 (n = 6)	**PDP2** (n = 6)	**PDP3** (n = 6)	**PDP4** (n = 6)	**All PDPs** (n = 24)
Temp.$_{20min}$ (°C)*	37.38 ± 0.23	36.29 ± 3.06	37.03 ± 2.55	34.83 ± 2.38	**36.38 ± 2.45**
Post-mortem pH					
pH_{20min}*	6.17 ± 0.16	6.26 ± 0.23	6.14 ± 0.16	6.05 ± 0.16	**6.15 ± 0.18**
pH_{24h}*	5.94 ± 0.15	5.95 ± 0.21	6.01 ± 0.15	5.77 ± 0.08	**5.92 ± 0.17**
Classification based on pH_{20min} post mortem					
Suspected PSE – count (%)	0 (0)	0 (0)	0	0	**0 (0)**
Suspected DFD – count (%)	0 (0)	1 (16.67)	1 (16.67)	1 (16.67)	**3 (12.50)**
Suspected meat with acceptable quality – count (%)	6 (100)	5 (83.33)	5 (83.33)	5 (83.33)	**21 (87.50**
Classification based on pH_{24h} post mortem					
Suspected PSE – count (%)	1 (16.67)	1 (16.67)	0	5 (83.33)	**7 (29.17)**
Suspected DFD – count (%)	0 (0)	0 (0)	0	0	**0 (0)**
Suspected meat with acceptable quality – count (%)	5 (83.33)	5 (83.33)	6 (100)	1 (16.67)	**17 (70.83)**

*Mean ± standard deviation
**Not determined because the slaughterhouse did not approve the request

Several authors agree that a pH value between 15–30 min can be used as an indicator of meat quality (Taylor and Jones 2004; Petracci *et al.* 2004; Zhang and Barbut 2005; Lesiow *et al.* 2009; Ristic and Damme 2010). Contrary to this claim, poor prediction of meat quality using post-mortem pH at 15 min was demonstrated in the study of Fraqueza and colleagues (2006) when the final characteristics of poultry meat such as lightness, drip loss, and cooking loss did not show significant relationship from early $pH_{15min.}$

Another indicator that is most commonly used in classifying the meat quality of poultry species like broiler chickens is the ultimate pH (Barbut 1993). The relationships between ultimate pH and meat quality have been extensively studied by several researchers and significant relationships are usually reported (*e.g.*, Barbut 1993, 1996; Sales and Mellett 1996; Fletcher 1999; Van Laack *et al.* 2000). Among all PDPs visited, PDP4 had the lowest average ultimate pH of 5.77 ± 0.08 followed by PDP1 (5.94 ± 0.15), PDP2 (5.95 ± 0.21), and PDP3 (6.05 ± 0.16). Based on the ultimate pH, no DFD meat was found among all samples. Suspected percentage of PSE meat was high in meat samples from PDP4 with 83.33%, followed by PDP1 and PDP2, both having a 16.67% of suspected PSE meat samples. A 100% suspected number of acceptable meat quality was recorded from samples at PDP3. Both PDP1 and PDP2 had 83.33% of the suspected number of acceptable meat quality while PDP4 had the lowest percentage at 16.67%. The high percentage of PSE from PDP4 may be associated with the stress of live chicken during long transport.

CONCLUSION

Ocular inspection of abattoir and evaluation of the ultimate pH of meat samples collected from each plant revealed that the design of a facility, handling of animals prior to slaughter, and slaughtering operations have a great impact on the quality – especially on the pH – of meat. Most of the visited hog slaughterhouses have a traditional design for simple but efficient carcass movement off the floor, while the PDPs need a lot of improvement to meet the minimum requirement for a standard slaughter facility. Government and relevant stakeholders interventions are also needed in terms of personnel training, as most of the workers lack awareness of hygienic slaughtering practices. In spite of unhygienic practices of some visited plants, acceptable meat quality in relation to PSE and DFD was still produced in those abattoirs.

Further researches on the relationship of meat quality traits with PSE and DFD are highly recommended, especially in the local setting. Moreover, other meat quality indicators such as color (L*, a*, b*), % drip loss, and texture (*e.g.*, firmness) are recommended to be included in the quality assessment and classifying of meat samples as PSE, DFD, and meat with acceptable quality in the future study. Information such as breed, feed diet, and handling practices at the farm level should be considered in future researches to determine all possible causes of quality defects. Larger sampling size and sampling schedules are also suggested to capture the differences in environmental temperature, practices, slaughter animals, among others. Nevertheless, the results of this experiment reiterate the importance of proper handling of animals prior to and during slaughter to avoid the incidence of PSE and DFD meats. Furthermore, the results of the study can be used as baseline information for further researches.

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