The Relationship between Muscle pH and Water-holding Capacity in Pork

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ABSTRACT

Meat quality of pork especially muscle pH and water-holding capacity is an important quality trait for the meat processing industry and consumer. The aim of this study was to investigate the relationship between muscle pH and water-holding capacity in pork. The samples were taken from *longissimus dorsi* muscle to evaluate the pH muscle at 45 min postmortem (p.m.) and 24 h p.m. and water-holding capacity (n=100). The results showed that pH at 45 min p.m. was positively correlated with muscle pH at 24 h p.m. (r=0.304; p<0.01). The muscle pH at 45 min p.m. was negatively correlated with drip loss (r=-0.434; p<0.01). The pH at 24 h p.m. was negatively correlated with drip loss (r=-0.561; p<0.01) and thawing loss (r=-0.522; p<0.01). Therefore, the postmortem pH muscle is important factors in determining the water-holding capacity of pork.

Keywords: Muscle pH, Water-holding capacity, Pork

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Introduction

Meat quality is an indicator of acceptability or preference for consumer, which the consumer's demand for high quality meat. The important quality traits for fresh meat are consisted of color, water-holding capacity, texture and fat distribution (Joo *et al*., 2013). After slaughter of an animal, aerobic metabolism turns to anaerobic glycolysis, glycogen stores are broken down to lactic acid that is accumulated in muscle, resulting in the pH decline in postmortem muscle (Apple and Yancey, 2013). Normally, pH declines gradually from 7.4 in living muscle to roughly 5.6 to 5.7 within 6 to 8 h of postmortem and then has an ultimate pH at 24 h (pH_u) about 5.3 to 5.7 (Scheffler and Gerrard, 2007). The muscle pH early p.m. has been used to monitor meat quality in fresh pork (Huff-Lonergan and Lonergan, 2007). PSE (pale, soft, exudative) have occurred when the pH of meat is lower than 6.0 at 45 min after slaughter. DFD (dark, firm, dry) has the ultimate pH p.m. measured after 12 to 48 hours higher than 6.0 (Adzitey and Nurul, 2011).

Water comprises approximately 75% of the weight of meat (Apple and Yancey, 2013), therefore water-holding capacity is the main quality attributes of fresh meat which influences consumer acceptance and the final weight of the product (den Hertog-Meischke *et al*., 1997). Water-holding capacity is refer to the ability of meat to retain its inherent water during force application and/or processing (i.e., cutting, pressing, grinding, packaging, curing, thermal processing, etc.) (Hamm, 1960). Losses of water (or purge) from meat can occur via evaporation, gravitational drip, thawing and cooking (Apple and Yancey, 2013). It has been estimated that as much as 50% or more of the pork produced has unacceptably high purge or drip loss (Huff-Lonergan and Lonergan, 2005).

Moreover, the key factors that determine water-holding capacity are rate and extent of pH decline. It has an impact on the structure of muscle (Huff-Lonergan and Lonergan, 2007), resulting in the decreased the ability of protein binding with water (den Hertog-Meischke *et al*., 1997), the state of shrinkage and denaturation of myofibrillar proteins (Scheffler and Gerrard, 2007). Pork with higher drip loss had the lower pH_u than the pork with lower drip loss (Faucitano *et al*., 2010).

Objective of the study

The aim of this study was to investigate the descriptive statistics and relationship between muscle pH and water-holding capacity in pork.

Materials and Methods

Animals and muscle samples

A total of 100 three crossbred [Duroc × (Large White × Landrace)] pigs were randomly obtained from a commercial slaughterhouse in Thailand. All pigs were slaughtered according to standard slaughtering procedures. The average of slaughter weight was 112.13 ± 4.81 kg. After electrical stunning, carcasses were scalded, cleaned, eviscerated and split. Muscle samples were immediately taken from the *longissimus dorsi* muscles at the 2^{nd} to 6^{th} of lumbar vertebra for further analysis.

Muscle pH

The muscle pH was measured at 45 min and 24 h p.m. using a pH meter with a spear-type electrode (pH Spear, Eutech Instruments, Singapore).

Water-holding capacity

Drip loss and thawing loss were conducted as water-holding capacity analyses. Drip loss was scored base on a bag method (Honikel *et al*., 1986) with a size-standardized sample from the *longissimus dorsi* collected at 24 h p.m. that was weighed, suspended in a plastic bag, held at 4 °C for 48 h, and thereafter re-weighed. Drip loss was expressed as a percentage.

Thawing loss was determined by calculating the difference in the pre-freezing and post-thawing weights. Thawed sample was cut from the *longissimus dorsi* collected at 24 h p.m. that was weighed and put into plastic bag and frozen at -20 °C until the analysis was to be performed by thawing at 4 °C for 24 h. Then the sample was absorbed with soft paper until dried and thereafter re-weighed (Jaturasitha *et al*., 2002). Thawing loss was expressed as a percentage.

Statistical analyses

All data were analyzed using SAS (SAS Inst. Inc., Cary, NC). Descriptive statistics of the muscle pH and water-holding capacity were evaluating the frequency distribution. Pearson's correlation coefficients were used for testing the relationships between muscle pH and water-holding capacity.

Results

The mean values, standard deviations and overall ranges for pH and water-holding capacity of the *longissimus dorsi* muscle from the pig population were shown in Table 1. The mean, minimum and maximum of muscle pH at 45 min p.m. was 6.20, 5.40 and 6.75, respectively. The mean, minimum and maximum of muscle pH at 24 h p.m. was 5.85, 5.44 and 6.49, respectively. For the water-holding capacity, the mean, minimum and maximum of drip loss was 3.61, 0.00 and 9.84, respectively. The mean, minimum and maximum of thawing loss was 5.22, 0.00 and 13.46, respectively. The distribution of muscle pH at 45 min p.m. showed a normal distribution. The highest proportion of pH at 45 min p.m. was a high pH (Figure 1). However, the pH at 24 h p.m. showed a distribution with a slight positive skew. The highest proportion of pH at 24 h p.m. was a low pH (Figure 2). The distribution for the water-holding capacity showed the large variations of the drip loss and thawing loss ranges in this pig population. The drip loss and thawing loss also showed distribution with a slight positive skew. The highest proportion of the drip loss and thawing loss was low (Figure 3, 4).

Table 1 Descriptive statistics of pH and water-holding capacity

Traits	Mean	SD	Min.	Max.
pH_{45} min	6.20	0.25	5.40	6.75
pH_{24} h	5.85	0.21	5.44	6.49
Drip loss, %	3.61	1.86	0.00	9.84
Thawing loss, %	5.22	2.29	0.00	13.46

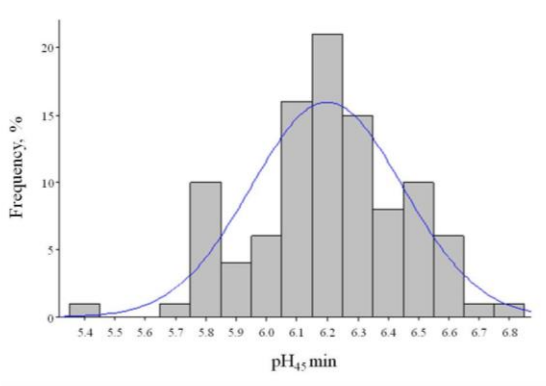

Figure 1 Distribution of muscle pH at 45 min p.m. in pork

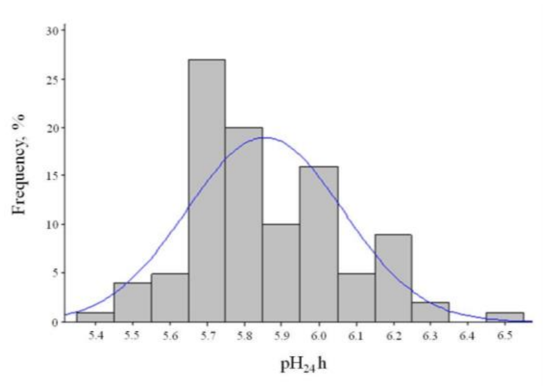

Figure 2 Distribution of muscle pH at 24 h p.m. in pork

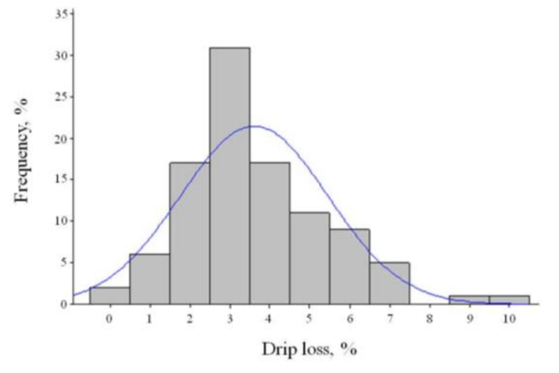

Figure 3 Distribution of drip loss in pork

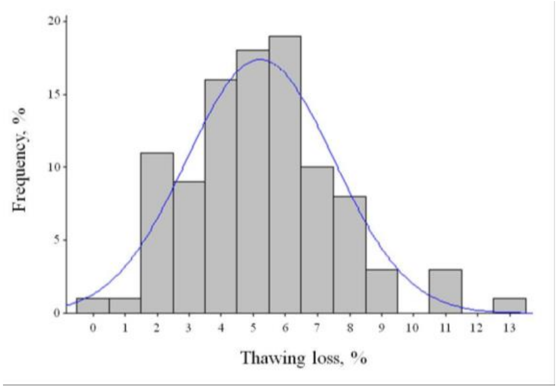

Figure 4 Distribution of thawing loss in pork

The correlation between muscle pH and water-holding capacity of pork were represented in Table 2. Muscle pH at 45 min p.m. was positively correlated with muscle pH at 24 h p.m. (r=0.304; p<0.01), but negatively correlated with drip loss (r=-0.434; p<0.01). Muscle pH at 24 h p.m. was negatively correlated with drip loss (r=-0.561; p<0.01) and thawing loss (r=-0.522; p<0.01). Moreover, drip loss was positively correlated with thawing loss (r=0.249; p<0.05).

Table 2 Correlation coefficients (r) between pH_{45} min, pH_{24} h, drip loss and thawing loss of pork; *p<0.05; **p<0.01.

Traits	pH_{45} min	pH_{24} h	Drip loss, %
pH_{45} min	-		
pH_{24} h	0.304**	-	
Drip loss, %	-0.434**	-0.561**	-
Thawing loss, %	0.012	-0.522**	0.249*

Discussion

The quality of meat relies heavily on the process of muscle to meat conversion. The measurement of muscle pH is the best indicator of muscle to meat conversion (Braden, 2013). After the muscle shifts to using anaerobic glycolysis as a major energy-generating pathway, the pH is reflective of the accumulation of lactic acid within the muscle and resulting in the pH decline in postmortem muscle. The muscle pH early postmortem (45 min) has been used to monitor quality differences in fresh pork (Huff-Lonergan and Lonergan, 2007). Also, the ultimate pH at 24 h p.m. is the best predictor of several important attributes of pork quality, including water-holding capacity, tenderness and color (Boler *et al*., 2010). The value for muscle pH at 45 min p.m. of normal meat is higher than 6.0 (Jaturasitha, 2008), while the range for muscle pH at 24 h p.m. is 5.3 to 6.0 (Warriss, 2000). If pH at 45 min and 24 h p.m. is less than 6.0 and 5.3, respectively, the meat is converted into PSE (Warriss, 2000). However, a meat above ultimate pH

6.0 was classified into DFD (Adzitey and Nurul, 2011). In this study, the muscle pH at 45 min and 24 h p.m. of pork were 6.20 and 5.85, respectively, which was defined in normal meat.

The water-holding capacity is affected by many factors in the whole meat production chain (den Hertog-Meischke *et al*., 1997). Drip loss had a wide range between 0 to 15% in pork (Adzitey and Nurul, 2011). The range of drip loss in this study was lower than other studies, which was reported between 0.21 to 16.51% (Borchers *et al*., 2007), 1.28 to 16.08% (Mörlein *et al*., 2007) and 2.20 to 20.7% (Warriss and Brown, 1987). According to the pH at 24 h p.m. of this study are high. The drip loss varied according to postmortem metabolism as a result of ATP degradation and the rate of acidification (Żelechowska *et al*., 2012). The faster pH decline cause denaturation of sarcoplasmic and myofibrillar proteins, resulting in reduced water holding capacity (Scheffler and Gerrard, 2007). In this study, the highest proportion of samples (56% of all samples) was lower than 3% drip loss that was defined in normal meat (Jůzl *et al*., 2012; Żelechowska *et al*., 2012). For the pork with drip loss higher than 4% (44% of all samples) is likely to incidence of PSE meat (Żelechowska *et al*., 2012). In addition, thawing is a quite important process following the freezing in terms of meat quality (Akhtar *et al*., 2013). The average thawing loss in this study was 5.22%. The previous study showed that the average thawing loss of commercial pigs was 5.81% (Dilger *et al*., 2010). This indicated that the water loss had increased in frozen and thawed pork. Due to tissue was damaged by the ice crystal formation during freezing and recrystallization during thawing (Kim *et al*., 2015).

Moreover, this study shows that muscle pH at 45 min p.m. correlated positively with muscle pH at 24 h p.m. According to the previous study, reported the positive correlation between muscle pH at 45 min with 24 h p.m. (r=0.32; Ryu *et al*., 2005). In meat science, pH has always been considered as an important determinant of meat quality (Boudjellal *et al*., 2008). Because of the end-product of postmortem glycolysis is lactic acid that is accumulated in muscle, resulting in the pH decline in postmortem muscle (Apple and Yancey, 2013). When the pH reaches the isoelectric point (pI) of the major proteins (pI = 5.4), the numbers of positive and negative charges on the proteins are essentially equal. These positive and negative groups within the protein are attracted to each other and result in a reduction in the amount of water that can be attracted and held by that protein (Huff-Lonergan and Lonergan, 2005). Also, the electrostatic forces that maintain the spacing between myofibrils are reduced, resulting in repulsion of structures within the myofibril is reduced. Water moves from the myofibril into the extramyofibrillar spaces, where it eventually is lost from the muscle cell (Apple and Yancey, 2013). This study indicated that increasing muscle pH p.m. was related to increasing water-holding capacity. The pH at 45 min p.m. was negatively correlated with drip loss. The pH at 24 h p.m. was also negatively correlated with drip loss and thawing loss. According to Kim *et al*. (2016), there is a positive correlation between ultimate pH with the water-holding capacity (r=0.17). Drip loss was a negatively correlated to pH at 45 min and 24 h p.m. (r=-0.40 and -0.50, respectively) (Ryu *et al*., 2005). Because of a lower pH causes an increased protein denaturation within the meat (Scheffler and Gerrard 2007). Accelerated denaturation can also cause greater shrinkage of the actomyosin bonds between the thick and thin filaments thus additionally reducing the amount of space within the myofibril for water to reside. The resulting meat is characterized as high water loss (Huff-Lonergan and Lonergan, 2007). Therefore, the decline in muscle pH drastically alters the water-holding capacity of meat (Braden, 2013).

Conclusions

The pork samples of this study were defined in normal meat. The rate of muscle pH decline after slaughter was affected on the water-holding capacity in pork. The muscle pH at 45 min p.m. correlated positively with muscle pH at 24 h p.m. Increasing muscle pH p.m. was related to increasing water-holding capacity. The pH at 45 min p.m. was negatively correlated with drip loss. The pH at 24 h p.m. was negatively correlated with drip loss and thawing loss.

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