Effects of Pre-slaughter Fasting and Chiller Ageing on Objective Meat Quality in *Longissimus Dorsi, Biceps Femoris,* and *Triceps Brachii* Muscles of Korean Native Black Pigs

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도축전 절식과 냉장숙성이 재래돼지 *Longissimus Dorsi, Biceps Femoris*와 *Triceps Brachii*의 육질에 미치는 영향

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적 요

본 연구는 한국 재래돼지의 도축전 절식과 숙성이 *longissimus dorsi*(LD), *biceps femoris*(BF) and *triceps brachii*(TB)의 육질에 미치는 영향을 조사하였다. 18 시간동안 절식은 LD에서 유의적으로($P < 0.05$) 높은 최종 pH을 보였고, BF도 유사한 경향을 나타냈다. 근육 온도는 절식유무에 영향을 받지않아, 이 결과는 각 처리구의 돼지들은 각기 다른 온도와 pH의 영향을 받았다는 것을 의미한다. 이러한 영향은 LD의 경우 절식을 하지 않은 돼지에서 유의적으로 높은($P < 0.05$) hunter L* 값과 가열감량에서 나타났다. 하지만 전단력은 차이가 없었다. 또한 BF와 TB의 육질은 도축전 절식유무에 의해 영향을 받지 않았다. LD에서 전단력은 숙성 7일까지 감소하였고, BF와 TB는 14일까지 유의적으로($P < 0.05$) 감소했다. 숙성기간중 LD와 BF, 그리고 LD와 TB의 상관관계를 보았을 때, LD의 전단력 6kg은 BF와 TB에서 각각 6과 3.5 kg을 보였다. 본 연구의 결과에 따르면, 도축전 급여는 시각적인 육색은 개선하나, 가열감량을 증가시켜 맛은 감소시킬 것으로 판단되었다. 한편 LD의 숙성은 7일이 적절한 것으로 나타났고, TB와 같이 근본적으로 연한 고기는 숙성은 가열감량을 증가시키므로 숙성하지 않는 것이 바람직하다고 판단되었다. BF와 TB에서는 14일 숙성은 연도는 증가하나 다즙성은 감소할 것으로 판단되었다.

(주요어 : Korean native pork, Fasting, Color, WB-shear force, Cooking loss)

I INTRODUCTION

Korean native black pig comprises approximately 0.74% of a total of 9.19 million pigs in Korea(Korean Ministry of Agriculture and Forest, 2003). However, Korean native pork(KNP) is one of the most in demand meats, because it has a particular high redness and chewiness compared with commercial landrace(Jin et al., 2001). The biological basis for these characteristics has yet to be known, but Kim et al. (2001a) reported that genetic component could be a factor.

Interaction between declines in pH and temperature during the onset of rigor is a central determinant of pork quality, as it has a direct influence on protein denaturation and myofibrillar

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shrinkage(Bertram et al., 2004; Rosenvold and Andersen, 2003), as well as in proteolysis(Hwang et al., 2003). Pre-slaughter fasting for approximately 12-15 h has been normally enforced to reduce muscle glycogen stores at the time of slaughter which can aggravate the extent and rate of pH decline(Rosenvold and Andersen, 2003; Wittmann et al., 1994; Eikelenboom et al., 1991). On the basis of visual appearance of KNP, the Korean domestic breed appeared to possess a higher frequency of red type fiber(Lindahl et al., 2001) which can be a direct factor associated with difference in response to pre-slaughter animal handling(Hernndez et al., 2004; Wood et al., 1996). Furthermore, pre-slaughter treatment can cause a diverse consequence to different muscles in terms of meat quality(Henckel et al., 2000; Stoier et al., 2001). In the latter study, pre-slaughter animal handing resulted in a significantly different pH-temperature profile which consequently affected meat quality.

To ensure the best pre-slaughter animal handling and chiller ageing, it is necessary to understand the effects of these practices on meat quality. However, in spite of the economic value of Korean native pork, only limited research has been made on these regards(Jin et al., 2001; Kim et al., 2001b). These studies have focused on longissimus muscle, but not on meat quality traits of other muscles. We also previously reported the effect of pre-slaughter fasting and chasing stress immediately prior to slaughter on longissimus meat quality(Hwang et al., 2004). The result showed that pre-slaughter physical stress for 15 min had negligible effect on objective meat quality. The current study evaluated the effects of 18-h feed withdrawal and chiller ageing for 14 d on objective meat quality traits in *longissimus dorsi*(**LD**), *biceps femoris*(**BF**), and *triceps brachii* (**TB**) of Korean native black pig.

Ⅱ MATERIALS AND METHODS

1. Animals, experimental design, and treatments

A total of 20 male Korean native black pigs (115 ± 18.2 kg, 13 months of age) were sampled from the National Livestock Research Institute (NLRI) breeding program. The pigs were conventionally transported to the NLRI abattoir, approximately 65 km away, with minimum transit stress. The pigs were assigned to a 2 × 2 × 4 factorial which were composed of two pre-slaughter feeding(ten pigs fasted for 18 h, and the other ten pigs fed until the morning of slaughter), two pre-slaughter stress(two sets of five pigs each from the feeding treatments were chased for 15 min in the lainage paddock immediately prior to slaughter, and two sets of five pigs each from the feeding treatments were handled with minimum stress), and four chiller ageing(1, 3, 7, and 14 d at 1℃ treatments. All pigs were stunned by an electronic stunner(230 volts for 2.5 sec), conventionally slaughtered, and placed in a 1℃ :hiller until the following day.

2. Sampling and objective meat quality measurements

Muscle temperature was logged at 5-min intervals for 24 h(Thermo Recorder, TR-50C, Japan) using thermocouples inserted into the geometrical center of the muscle between the 3rd and 4th lumbar vertebrae and proximal end of BF from approximately 30 min after stunning, until the following day. The pH was measured using a portable needle-tipped combination electrode (NWKbinar pH-K21, Germany) at approximately 15-min intervals in the center of the muscle between the 3rd and 4th lumbar vertebrae and proximal end of BF from approximately 30 min postmortem, until the muscle was judged to have reached ultimate pH. Another measurement was made the following day, approximately 24 h postmortem.

The day after slaughter, LD(from the 7th thoracic vertebrae to the last lumbar vertebrae), BF and TB muscles were removed, cut into three potions, vacuum packed, and randomly assigned to one of four ageing periods(1, 3, 7, and 14 d, for LD; and 1 and 14 d for BF and TB) for objective measurements of WB-shear force and meat color. The samples were held at 1℃ for the relevant ageing period. WB-shear force was measured on cooked steaks(2.54-cm thick) according to the method described by Wheeler et al.(2000). Sarcomere length was determined at 24 h using a Helium-Neon laser diffraction technique according to the method described by Cross et al.(1981). Cooking loss was determined by calculating percentage of weight loss during cooking (ca. 300 g) for WB-shear force measurement. Objective meat color was determined by a Minolta Chromameter(CR300, Minolta, Japan) on freshly cut surface after a 30-min blooming at 1℃

3. Statistical analysis

The effects of pre-slaughter treatments and ageing on objective meat quality traits were evaluated by analysis of variance using a mixed model(SAS, 1997). Models included fixed effects of feeding, stress, ageing time, sampling location, and the first order interactions, with animal as a random term. Based on the same experiment, Hwang et al.(2004) concluded that pre-slaughter stress had no effect on longissimus muscle. While pre-slaughter stress was included in the treatment, the current study did not present the effect of pre-slaughter stress. Sampling location was retained in the model as it was necessary to have it adjusted, regardless of the level of probability. The significant difference of means ($P < 0.05$) was separated by a least-significant-difference test(a pair-wise t-test).

Ⅲ RESULTS AND DISCUSSION

1. Effect of pre-slaughter feed withdrawal on objective meat quality traits

The conversion of muscle to meat is an energy-demanding biological process and initial energy reserves exert a significant influence on meat quality traits through its effect on interactions between pH and temperature during the process. Pre-slaughter feed withdrawal for approximately 12-15 h is a common practice to reduce the risk of microbial cross-contamination, as well as mortality during transport(Rosenvold and Andersen, 2003; Warriss, 1994). Furthermore, it improves water-holding capacity and meat colour by way of reducing initial glycogen content and the rate and extent of glycolysis(Wittmann et al., 1994; Eikelenboom et al, 1991). The current study examined the effect of 18-h fasting on objective meat quality in three muscles of Korean domestic pigs. Table 1 presents the effects of pre-slaughter fasting on different muscles during chiller ageing.

At first glance, the feed withdrawal resulted in a significantly higher($P < 0.05$) ultimate pH for LD. In addition, while there was no significant difference for BF at 24 h, there was a numeric tendency for a higher ultimate pH, similar to that reported by Witmann et al.(1994). On the other hand, the fasted animals had significantly($P < 0.05$) lower pH at 1.5 h for both muscles. This suggests that the difference in ultimate pH was more likely affected by external factors such as pre-slaughter animal handling rather than physiological muscle properties. Also, it shows that pigs with different pre-slaughter feeding had

Table 1. Least significant means, F ratios, and significance levels for pH, temperature(Temp), sarcomere length(sarco), and objective meat quality traits as a function of 18-h feed withdrawal prior to slaughter and chiller ageing

	Feed withdrawal			Ageing(d)					Model terms	
	18 h	No	Av. se	1	3	7	14	Av. se	Feed	Ageing
Longissimus dorsi										
pH at 1.5 h	6.5	6.6	0.04						9.94***	
Temp at 1.5 h (℃	33.3	33.4	0.56						0.03	
pH at 24 h	6.2	5.8	0.04						47.3***	
Temp at 24 h (℃	0.6	1.2	0.12						14.8***	
Sarco (μm)	1.8	1.9	0.03						0.22	
Peak force (kg)	6.1	5.5	0.49	7.4[a]	6.1[b]	5.2[c]	4.6[c]	0.40	0.93	25.5***
Cooking loss (%)	21.1	26.0	1.12	22.6[a]	23.4[a]	23.3[a]	24.9[b]	0.86	9.56**	6.06**
Hunter L*	34.1	38.9	0.95	35.5[a]	36.1[a]	36.3[a]	37.9[b]	0.73	12.7***	9.65***
Hunter a*	8.6	9.5	0.52						1.4	NS
df[Ω]									1/18, 1/54, 1/57	3/54
Biceps femoris										
pH at 1.5 h	6.5	6.8	0.07						8.50**	
Temp at 1.5 h (℃	36.6	36.3	0.83						0.06	
pH at 24 h	6.1	5.9	0.07						3.24	
Temp at 24 h (℃	1.4	2.3	0.27						5.46*	
Peak force (kg)	5.3	6.1	0.40	6.7			4.7	0.40	1.95	12.2**
Cooking loss (%)	19.7	21.8	0.91	18.4			23.0	0.91	1.72	24.8***
Hunter L*	31.6	33.4	0.76						2.95	NS
Hunter a*	10.5	10.4	0.46						0.94	NS
df[ϕ]									1/18, 1/19	1/18
Triceps brichii										
Peak force (kg)	3.4	3.8	0.21	3.89			3.32	0.17	1.28	19***
Cooking loss (%)	19.3	20.7	1.03	17.81			22.19	0.88	0.83	20.1***
Hunter L*	31.1	31.9	0.66						0.64	NS
Hunter a*	11.8	11.2	0.50						0.66	NS
df[ω]									1/18, 1/19	1/18

NS : Not significant($P > 0.05$), * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

[abc] Means bearing the same letter within each row did not differ significantly($P > 0.05$).

[Ω] df : numerator/denominator degree of freedom., pH, temperature and sarcomere length = 1/18, peak force, cooking loss, hunter L* = 1/54, Hunter a* = 1/57.

[ϕ] df : numerator/denominator degree of freedom., pH, temperature and sarcomere length = 1/18, hunter L* and a* = 1/19.

[ω] df : numerator/denominator degree of freedom., Peak force and cooking loss = 1/18, hunter L* and a* = 1/19.

different pH-temperature profile during rigor development, which similarly occurred in various muscles(Eikelenboom et al., 1991). Even though muscle temperature did not differ between the treatments, BF showed approximately a 3℃ higher temperature than LD at 1.5 h(during rigor development). At the same time, pH was similar for both muscles, as shown by Henckel(2000). This indicates that BF was exposed to higher pH-temperature interactions during the onset of rigor compared to LD. Enfalt et al.(1993) previously reported that pale, soft, exudative(PSE) meat was related not only to a lower initial pH, but also to a faster decline in pH. In this regard, the current result suggests that the level of initial energy reserves was related to the rate and extent of glycolysis. A lower pH at 1.5 h and higher pH at 24 h for fasted pigs supported this notion.

However, pH and temperature profile during rigor development had different effects on objective meat quality depending on the muscles. The result showed that drip loss and hunter L* were significantly($P < 0.05$) higher for pigs fed until the morning of slaughter, and had a faster pH decline. This was in agreement with previous studies(Rees et al., 2003; Hwang and Thompson, 2001) which showed that a rapid decline in pH resulted in increased drip loss and lightness. This might be a consequence of protein denaturation (Offer, 1991) which increased reflectance on tissue surface(Pearson and Dutson, 1985). On the other hand, the feeding treatment did not affect any of the objective meat qualities for both BF and TB. In terms of the effect of pH and temperature profile on meat quality, the current result indicated that the LD muscle was more susceptible than the other muscles. Similarly, Stoier et al.(2001) observed that LD was more influenced by the difference in pH, caused by pre-slaughter stress, than BF and semimembranosus muscles. This was also evidenced by the magnitude of difference in cooking loss between the muscles. The fasted pigs showed similar cooking loss between the muscles with approximately 19 ~ 21%. On the other hand, when pigs were fed until the morning of slaughter, cooking loss for LD was increased to 26% while the other muscles had no such increase. In the study of Rosenvold et al.(2002), LD and BF showed similar response to pre-slaughter treatments in terms of water-holding capacity, assessed by drip loss, despite the treatment greatly accelerated decline in pH for both muscles. The discrepancy might be partly contributed to genetic parameters. It has been shown that the effect of genotype was of importance in meat quality traits as different breeds display different muscular characteristics(Monin et al., 1986), and genotypic differences were reflected by susceptibility to external stress(Fuji et al, 1991). However, it was more likely related the fact that the previous study(i.e., Rosenvold et al., 2002) enforced exercise treatment prior to slaughter, which could generate more significant effect on hind legs in terms of levels of glycogen reserves and muscle temperature. LD and BF predominantly consist of type IIB(intermediate) muscle fibres(Leseigneur-Meyneir and Grandemer, 1991). Given this, the current result showing lower hunter L* value in the BF muscle was likely a consequence of higher pigment content in this muscle, also shown by the high hunter a*. This trend was similar to the result of D'Souza et al.(1998).

Hunter L* value and cooking loss was constant at 7-d chiller ageing for LD, followed by a significant($P < 0.05$) increase at 14 d. The objective quality traits for BF and TB were not determined at 3 and 7 d due to the limited size of muscle samples, but the significant($P < 0.05$) increases in hunter L* value and cooking loss at 14 d compared to 1 d were consistent with the LD muscle. These indicated that meat color and water-holding capacity for Korean native pork were relatively stable at 7-d chiller ageing for the three muscles.

Sarcomere length for LD indicated that there was no muscle shortening, with an average of 1.85 μm. WB-shear force did not differ between the pre-slaughter groups for the three muscles. The result was particularly of interest because the pH and temperature profiles during the onset of rigor was significantly affected by the pre-slaughter treatment, under which circumstance significantly different proteolysis could take place between the treatments(Hwang et al., 2003; Rees et al., 2003). On the other hand, there was a numeric tendency of lower shear force for the pigs fed until the morning of slaughter. This concurred with a faster pH decline and a lower ultimate pH. The coincidence might mirror that the previous results (e.g., Hwang and Thompson, 2001) which showed that rapid decline in pH during rigor development brought about an early activation of the calpain system and consequently resulted in tender meat. WB-shear force showed significant ($P < 0.05$) linear reductions from 1 to 7 d at 1℃ while BF and TB showed significantly($P < 0.05$) lower WB-shear forces at 14 d than at 1 d. The result indicated that a significant postmortem tenderization for LD was achieved at 7 d, but the other two muscles continued until 14 d. This suggested that BF and TB required longer chiller ageing time for the best tender meat compared to LD. However, it did not mean all muscles should be aged for that period, because TB muscle is a naturally tender muscle, as seen by its WB-shear force at 1 d(i.e., 3.89 kg) which was more tender than a 14-d aged LD muscle. On the basis of WB-shear force measurement, TB does not require postmortem tenderization.

In general, pre-slaughter fasting appeared to have an adverse effect on meat color for LD, while reduced cooking loss could improve palatability. Given this, reaching an industrial conclusion is an intricate process due to the presence of both beneficial and detrimental effects. Further studies are necessary using an industrial population, as the current animals in this study were sampled only from an experimental population. Nevertheless, it was important to note that the treatments had negligible effects on the other two muscles. A 7-d chiller ageing was likely the best practice for LD, because cooking loss significantly increased at 14 d, while tenderization was completed by that time. Chiller ageing seemed not necessary for naturally tender TB because it rather increased cooking loss. As chiller ageing for 14 d increased both tenderness and cooking loss of BF, the effect of their interactions on palatability and appropriate ageing time has remained unanswered.

2. Relationship between major muscles and objective meat quality traits

While the current study did not focus on the relationship between meat quality traits and muscles, it was of interest to note such a relationship during ageing time. It has been reported that WB-shear force tended to account for the shearing property of the myofibril component (Harris and Shorthose, 1988). This was reflected by a study on beef where simple correlation coefficients between WB-shear force and trained sensory tenderness varied from 0.0 for gluteus medius to 0.73 for longissimus(Shackelford et al., 1995). In addition, meat color and its stability during chiller ageing varied depending on the muscle type and pH-temperature profile during rigor development(Rees et al., 2003; Leseigneur-Meyneir and Grandemer, 1991).

Fig. 1 presents the relationship between LD, BF, and TB in WB-shear force and objective meat color. There was a considerable difference in regression slopes in the relationship between LD and TB(comparison 1) and LD and BF(compar-

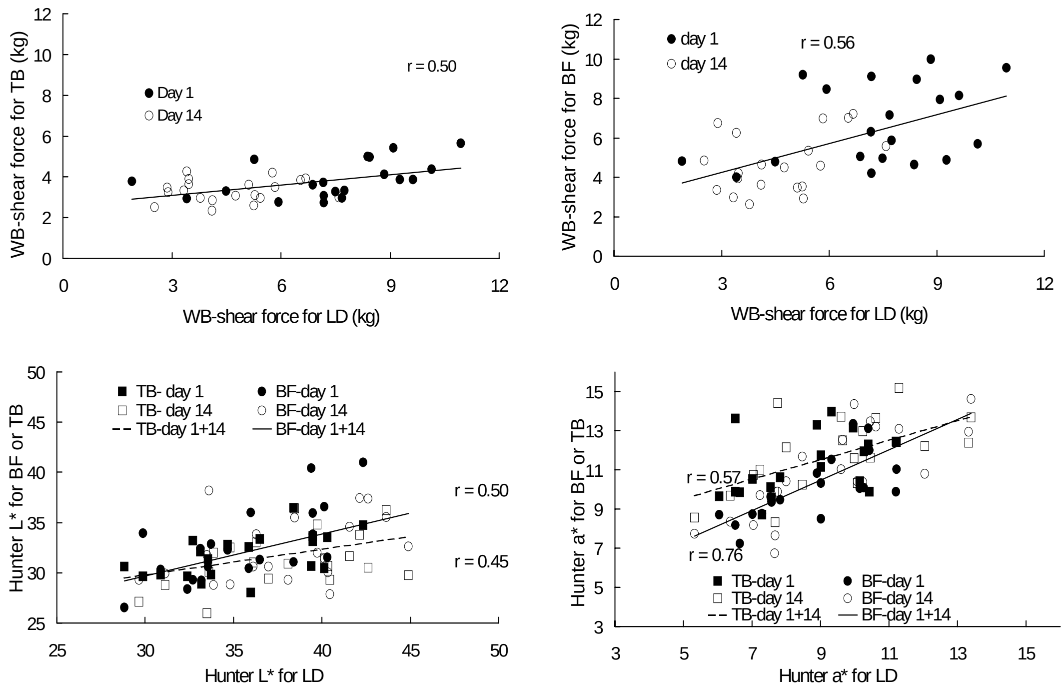

Fig. 1. Simple correlation between *longissimus dorsi*(LD), *biceps femoris*(BF) and *triceps brachii*(TB) muscles for WB-shear force and objective meat color.

ison 2) in that the slope for comparison 1 was lower than that for comparison 2. The simple correlation coefficients ranged from 0.50 to 0.56. This indicated that when LD tenderness was used as a reference, prediction equation and confidence level varied depending on the muscle. For instance, a 6 kg of shear force for LD was equivalent to approximately 3.5 and 6 kg for TB and BF, respectively. It has been shown that skeletal muscles had different rates of tenderization due to their diverse properties in enzyme system, structural figure, and geological location(Sentandreu et al., 2002: Purslow, 2002; Tornberg, 1996). In this regard, the relationship might differ during ageing, but the aspect could not be examined by using only 20 animals.

On the other hand, objective color parameters showed largely similar relations between comparisons 1 and 2. It could be noted in the relationships that simple correlation coefficients for hunter a* values was substantially higher than those for hunter L* values. The result partly shows the difference in the rate and extent of protein denaturation and content of pigment. This would be an area for further studies in Korean native pig.

Ⅳ ABSTRACT

This study evaluated the effects of pre-slaughter feed withdrawal and chiller ageing on objective meat quality traits in *longissimus dorsi* (LD), *biceps femoris*(BF), and *triceps brachii*(TB) muscles of Korean native black pigs. Twenty males were assigned into a 2(pre-slaughter feeding) × 2(pre-slaughter stress) × 4(chiller ageing) factorial. Pre-slaughter fasting for 18 h resulted in significantly($P < 0.05$) higher pHs at 1.5 h for

both LD and BF. On the other hand, muscle temperature did not differ between the fasted and fed animals. The result implied that pigs with different pre-slaughter feedings experienced different pH-temperature profiles during rigor development. This was reflected by the significant($P < 0.05$) increase in cooking loss and hunter L* for LD of the fed pigs. However, WB-shear force of LD was not affected by the treatment. Furthermore, objective meat quality of BF and TB did not differ between the treatments. Hunter L* value and cooking loss for LD were constant for 7 d, followed by a significant($P < 0.05$) increase at 14 d. BF and TB had significantly($P < 0.05$) higher hunter L* value and cooking loss at 14 d than at 1 d. Significant($P < 0.05$) linear reductions in LD WB-shear force took place from 1 to 7 d, while BF and TB WB-shear forces were significantly ($P<0.05$) reduced at 14 d. Simple correlation for WB-shear force between LD and BF, and between LD and TB indicated that 6 kg of shear force for LD was equivalent to approximately 3.5 and 6 kg for TB and BF, respectively. On the basis of the current result, feeding until the morning of slaughter appeared to contribute to favourable meat color for LD. However, negative effect on palatability due to increase in cooking loss should be taken into account. A 7-d chiller ageing was likely the best practice for LD, while TB appeared not to require chiller ageing. A 14-d ageing could improve the tenderness of BF, but could likely reduce juiciness.

(**Key words**: Korean native pork, Fasting, Color, WB-shear force, Cooking loss)

Ⅴ ACKNOWLEDGMENT

The authors acknowledge the support from the RDA Grant for Bio-21 projects.

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(접수일자 : 2004. 2. 10. / 채택일자 : 2004. 4. 16.)