Correlations of blood lactate content at exsanguination to objective and subjective tenderness of pork loin

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Abstract—**The purpose of this study was to investigate the correlations between blood lactate content and meat $pH_{24\ h}$, tenderness measured by objective (Warner-Bratzler shear force & texture profile analysis) and subjective (sensory evaluation) ways. For this study, a total of 108 (Duroc=80, Landrace=20, and Yorkshire=8) pigs were used for measuring blood lactate content at exsanguination, and a total of 108 pork loins were used for meat $pH_{24\ h}$, WBS, TPA-hardness, and sensory hardness and initial hardness. Meat $pH_{24\ h}$ was correlated to WBS ($r=-0.44$, $P<0.001$), and TPA-hardness ($r=-0.45$, $P<0.001$). However, $pH_{24\ h}$ was not significantly related to sensory initial tenderness parameters (sensory hardness & initial hardness). Tenderness parameters measured by objective and subjective ways were significantly related to each other. Blood lactate content measured at exsanguination was correlated to meat $pH_{24\ h}$ ($r=-0.38$, $P<0.001$), WBS ($r=0.42$, $P<0.001$), and TPA-hardness ($r=0.21$, $P<0.05$). However, significant correlations between blood lactate content and sensory initial tenderness parameters were not observed. Consequently, these results indicated that blood lactate content at exsanguination was correlated to objective tenderness of meat such as WBS and TPA-hardness, and meat with lower blood lactate content are more tender at first penetration compared to meat with higher blood lactate content.**

Keywords— **Blood lactate content, Meat pH, Tenderness**

I. INTRODUCTION

The eating quality of meat is the major determinant of meat quality, and determinants of meat eating quality are multifactorial and complex [1]. The most important elements in eating quality are tenderness, juiciness, and flavours. However, tenderness is considered as the important attribute for eating quality [2], and the main source of consumer complaint and the primary cause of failure to repurchase is the variability in tenderness [1]. One of the determinants of tenderness is the rate and extent of pH. In general, meat with low ultimate pH (pH_u) has poor tenderness because the enzymes involved in postmortem tenderization are inhibited by acidification, and low pH_u is also associated with increased drip loss resulting in lower acceptable meat [1].

Tenderness can be evaluated by objective and subjective ways. Objective methods for measuring tenderness include Warner-Bratzler shear force (WBS) and texture profile analysis (TPA), especially hardness. Sensory evaluation is the common methods for subjective evaluation of tenderness. WBS, TPA, and sensory evaluation of tenderness are significantly related to each other [3].

Glycolysis is essential part of the postmortem metabolism, resulting in the decline of muscle pH. The rate and extent of pH decline during the conversion of muscle to meat impact significantly on the development of fresh meat quality [4]. The onset of rigor mortis at low pH and high temperature causes the denaturation of myofibrillar and sarcoplasmic proteins, especially denaturation of myosin. The sever denaturation of muscle proteins results in stiff and shortened structure, and decrease water holding capacity. Thus, consumers generally perceive the meat with sever protein denaturation is tough [4, 5]. Moreover, recent study showed that blood metabolite contents are significantly related to muscle pH, protein denaturation, and pork quality traits [6, 7]. Especially, blood lactate concentration measured at exsanguination significantly correlated to muscle pH at 60 min postmortem [7].

Therefore, the purpose of this study was to investigate the correlations between blood lactate content and meat pH, tenderness measured by both objective (WBS & TPA) and subjective (sensory evaluation) ways.

II. MATERIALS AND METHODS

A. Animals and muscle samples

A total of 108 (Duroc=80, Landrace=20, and Yorkshire=8) pigs were evaluated. Treatment conditions both before and after slaughter were similar for all pigs. They were transported to a commercial slaughter plant under the same handling conditions when their live weight was similar (110 ± 5 kg). The slaughter plant used electrical stunning and a traditional scalding-singeing process. Following electrical stunning, the pigs were exsanguinated, and blood samples were collected to measure blood lactate content. After 24 h of chilling in 4 °C room, muscle samples were taken from the pork loin at the 10th–15th thoracic vertebra for the measurement of objective and subjective tenderness.

B. Blood lactate content

Blood samples were collected at the slaughter plant during exsanguination using 10.0 ml tubes (BD Vacutainer® treated with sodium fluoride and potassium oxalate, Becton Dickinson). The blood lactate content of the samples were measured immediately using portable lactate analyser (Lactate Scout, SenseLab Inc.).

C. Meat pH

Meat pH were measured in a cold room at 24 h postmortem ($pH_{24\ h}$) directly on the carcasses a portable pH meter (HM-17MX, TOADKK, Japan).

D. Objective tenderness measurements

For measurements of objective tenderness, WBS and TPA were assessed. Samples were cut into 2 cm thick chops. Pork chops from each sample were cooked to a final core temperature of 71 °C in the water bath. After cooking, six cores (1.27 cm diameter), parallel to the longitudinal orientation of the muscle fibers, were taken from each pork chop for WBS assessment. For TPA, pork chops were cut into 2.0 cm^3 pieces without a cooked surface.

WBS was determined using an Instron Universal Testing Machine (Model Series IX; Instron Co., Norwood, MA, USA) with Warner-Bratzler shearing device. The samples were sheared perpendicular to the long axis of the core.

Texture of meat were analysed in a textrometer TA-XT Express (Stable Micro Systems, Surrey, England). Test condition was followed by the methods of Ruiz de Huidobro et al. [8]. TPA of each sample was measured using more than 10 cubes. The force-by-time data from each test were used to calculate the mean values for the TPA hardness of each chop [9].

E. Subjective tenderness evaluation

Sensory evaluation was performed to evaluate the subjective tenderness of meat. Samples were cut into 2 cm thick steaks. Steaks were roasted in an oven (Hauzen HS-XC364AB, Samsung, Korea) set at 180 °C and turned every 3 min until cooked to an internal temperature of 71 °C. Cooked steaks were cut into 1.3 cm^3 pieces that were given randomly to panellists to minimize bias. Ten trained panellists were assigned to separate sensory booths at Korea University to evaluate the sensory quality of the pork samples. Panellist training was performed according to published sensory evaluation procedures [10], and lasted over 6 weeks. A total of 22 sessions were conducted, with ten samples evaluated per session. Cooked samples were evaluated for sensory hardness (force required to compress the meat sample placed between molar teeth; 1 = very soft, 5 = very hard) and initial hardness (force required to chew 3 times after the initial compression; 1 = very tender, 5 = very tough) with 5 cm unstructured line scale [11]. Sensory evaluation of each sample was conducted twice, and the average value was used.

F. Statistical analysis

Descriptive statistics were calculated using the MEANS procedure of the SAS software.

Pearson partial correlation coefficients were evaluated to characterize the correlations between the blood lactate content, meat pH, and objective and subjective tenderness parameters.

III. RESULTS AND DISCUSSION

Table 1 shows descriptive statistics of blood lactate content, meat $pH_{24\ h}$, WBS, TPA-hardness, and sensory initial tenderness parameters including hardness and initial harness. Blood lactate content measured at exsanguination has the highest coefficient of variation (CV=43.27%), whereas meat pH measured at 24 h postmortem showed the lowest coefficient of variation (CV=2.50%).

Results of correlation analysis were presented in Table 2. As expected, objective and subjective tenderness parameters were significantly correlated each other. Moreover, meat pH measured at 24 h postmortem was significantly related to WBS (r=−0.44, P<0.001) and TPA-hardness (r=−0.45, P<0.001). However, ultimate meat pH was not significantly related to sensory initial tenderness parameters.

Blood lactate content at exsanguination was significantly correlated to meat $pH_{24\ h}$ (r=−0.38, P<0.001). Blood lactate content showed similar tendency to meat $pH_{24\ h}$. Blood lactate was significantly correlated to WBS (r=0.42, P<0.001) and TPA-hardness (r=0.21, P<0.05). However, there was no significant correlation between blood lactate content and sensory initial tenderness parameters.

IV. CONCLUSION

The results of this study revealed that blood lactate content at exsanguination was correlated to objective tenderness of meat such as WBS and TPA-hardness, and meat with lower blood lactate content are more tender at first penetration compared to meat with higher blood lactate content.

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REFERENCES

1. Maltin C, Balcerzak D, Tilley R, et al. (2003) Determinants of meat quality: tenderness. P Nutr Soc 62:337-347
2. Aaslying MD, Bejerholim C, Ertbjerg P, et al. (2003) Cooking loss and juiciness of pork in relation to raw meat quality and cooking procedure. Food Qual Prefer 14:277-288
3. Caine WR, Aalhus JL, Best DR, et al. (2003) Relationship of texture profile analysis and Warner-Bratzler shear force with seneory characteristics of beef rab steaks. Meat Sci 64:333-339
4. Scheffler TL, Gerrard DE (2007) Mechanisms controlling pork quality development: The biochemistry controlling postmortem energy metabolism. Meat Sci 77:7-16
5. Jensen WK (2004) Encyclopedia of Meat Sciences. Elsevier, England
6. Choe JH, Choi YM, Lee SH, et al. (2009) The relation of blood glucose level to muscle fiber characteristics and pork quality traits. Meat Sci 83:62-67
7. Edwards LN, Engle TE, Correa JA, et al. (2010) The relationship between exsanguination blood lactate concentration and carcass quality in slaughter pigs. Meat Sci 85:435-440.
8. Ruiz de Huidobro F, Miguel E, Blazquez B, et al. (2005) A comparison between two methods (Warner-Bratzler and texture profile analysis) for testing either raw meat or cooked meat. Meat Sci 69:527–536
9. Bourne MC (1978) Texture profile analysis. Food Technol 33:62–66
10. Meilgaard M, Civille GV, Carr BT (1991) Sensory evaluation techniques. Boca Ranton, FL
11. Fortin A, Robertson WM, Tong AKW (2005) The eating quality of Canadian pork and its relationship with intramuscular fat. Meat Sci 69:297-305

Table 1. Descriptive statistics of blood lactate content, meat $pH_{24\ h}$, WBS, TPA-hardness, and sensory initial tenderness parameters

	Mean ± SD	Min	Max	CV
Blood lactate[1] (mmol/l)	11.72 ± 5.07	2.60	23.40	43.27
Meat $pH_{24\ h}$	5.69 ± 0.14	5.44	6.29	2.50
WBS[2] (N)	42.65 ± 10.57	22.47	78.70	24.79
TPA[3]-hardness (N)	27.66 ± 4.19	18.51	38.08	15.14
Sensory-hardness	3.32 ± 0.47	1.95	4.46	14.18
Sensory -initial hardness	3.42 ± 0.51	2.00	4.71	14.90

[1] Blood lactate content measured at exsanguination.
[2] Warner-Bratzler shear force.
[3] Texture profile analysis.

Table 2. Correlation coefficients among blood lactate content, meat $pH_{24\ h}$, WBS, TPA-hardness, and sensory initial tenderness parameters

	Meat $pH_{24\ h}$	WBS[2]	TPA[3] -hardness	Sensory -hardness	Sensory -initial hardness
Blood lactate[1]	-0.38***	0.42***	0.21*	-0.06	-0.08
Meat $pH_{24\ h}$		-0.44***	-0.45***	-0.12	-0.11
WBS[2]			0.54***	0.22*	0.23*
TPA[3]-hardness				0.48***	0.50***
Sensory-hardness					0.95***

Level of significance: * $P<0.05$, *** $P<0.001$.
[1] Blood lactate content measured at exsanguination.
[2] Warner-Bratzler shear force.
[3] Texture profile analysis.