HAND-HELD LACTATE ANALYZER AS A TOOL FOR THE REAL-TIME MEASUREMENT OF BLOOD LACTATE DURING SLAUGHTER AND PORK QUALITY PREDICTION

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Abstract – A total of 600 pigs was randomly chosen on arrival at a commercial slaughter plant and sampled for lactate analysis from the ear vein using a Lactate Scout Analyzer (LSA) at unloading (UN), after lairage (LA), in the restrainer (RE; before stunning), and from the ear vein (EX1) and the bleeding incision (EX2) at exsanguination. Pigs were distributed into two pen groups, one kept in lairage overnight (G1) and the other kept between 2 and 3 h before slaughter (G2). Meat quality was assessed in the *Longissimus dorsi* (LD), S*emimembranosus* (SM) and *Adductor* (AD) muscles. Data were analyzed using Spearman correlations and the MIXED procedure of SAS. Greater ($P = 0.009$) levels of blood lactate were found in pigs laired longer, which resulted in LD and SM muscles with greater pHu ($P = 0.03$ and $P = 0.001$, respectively), as well as lower L* ($P = 0.005$ and $P = 0.008$, respectively) and drip loss ($P = 0.01$ and $P = 0.02$, respectively). The greatest correlation with lactate levels was observed at LA with pHu value of the SM and AD muscles ($r = 0.40$; $P < 0.001$). LSA lactate levels reliably reflect the physiological response of pigs to preslaughter procedures and may help explain the variation in pork quality as measured in the ham muscles.

Key Words - animal welfare, handling, lactate, meat quality, preslaughter stress.

I. INTRODUCTION

Muscular activity requires energy, which is provided by the breakdown of glycogen in the skeletal muscles. During intense muscular activity the oxygen supply is often insufficient, so the energy is released through an anaerobic process which converts pyruvate to lactate [1]. Therefore, high levels of lactate can be found in the blood of very disturbed or frightened animals or when there is some muscle damage (bruising) caused by vigorous physical exercise [3]. Previous studies have associated higher values of lactate to poor pork quality [4, 5].

As blood lactate is not influenced by post-stunning carcass handling [6], its measurement actually mirrors the physiological condition of pigs prior to slaughter. Hence, for practical reasons, there is a need to develop an on-line blood lactate measurement alternative to the traditional time-consuming enzymatic analytical procedure. Such a tool would allow the monitoring of lactate variation in commercial conditions and would assist in the development of improved animal handling methods before stunning. For this reason, based on its strong correlation ($r = 0.97$) with the enzymatic procedure [4], the hand-held Lactate Scout Analyzer is being increasingly used for the measure of blood lactate at swine slaughter. It was originally used in sports to predict athletic endurance performance. Unfortunately, the correlations between LSA lactate and pork quality traits obtained in previous studies [6] were weak (up to $r = 0.32$), although significant. This was most probably due to the small sample size, the low-stress marketing conditions and the use of the loin muscle for meat quality evaluation. Indeed, the LD muscle may not be the most suitable muscle to study meat quality variation in relation to physical stress [7].

Therefore, the objectives of this study were to assess the relationship between blood lactate variation at the plant and pork quality variation (in loins and hams) on a large sample size and under

commercial preslaughter handling conditions in order to validate its reliability as a pork quality predictor.

II. MATERIALS AND METHODS

Animals and treatments

A total of 600 pigs was randomly chosen on arrival at a commercial slaughter plant and sampled for lactate analysis at unloading (UN), after lairage at the exit of the resting pen (LA), in the restrainer (RE; before stunning) and at slaughter (EX1) over 6 slaughter days (100 pigs per day). On each day, pigs were distributed into two groups of 50 pigs each, with one group being held in lairage overnight (G1), and the other being held in lairage between 2 and 3 h before slaughter (G2).

Blood lactate analysis

Blood samples were collected by picking one of the animal's distal ear veins with a retractable gauge needle. A drop of blood from the animal's ear was immediately dripped onto a sample strip (two strips/animal) and inserted into a hand-held Lactate Scout Analyzer (LSA; EKF Diagnostic GmbH, Magdeburg, Germany). The blood lactate measurement was obtained in approximately 15 s. After electrical stunning (head-to-chest), exsanguination blood was both collected from the ear (EX1) and from the bleeding wound (EX2). At EX2, blood was collected in a plastic cup and lactate level was immediately assessed in duplicate with the LSA by dipping the test strips blood in the collected sample, in order to collect 0.5 µl of blood in each strip.

Meat quality assessment

Meat quality was evaluated on 25 carcasses selected from each of the respective lairage groups. Muscle pH was measured at 30 min post-mortem in the *Longissimus dorsi* (LD) and *Semimenbranosus* (SM) muscles and at 24 h post-mortem in the same muscles and in the *Adductor* (AD) muscle by means of a portable pHmeter (Oakton Instruments Model pH 100 Series, Vernon Hills, IL). The light reflectance was measured by a Minolta Chromameter (CR 300; Konica Minolta, Sensing Americas Inc. New Jersey, USA) according to the reflectance coordinates (CIE L*, a*, b*) and the drip loss according to a modified EZ-DripLoss procedure, 24h *post mortem* in the LD and SM muscles [8]. Data were analyzed using Spearman correlations and the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). The model included the group as a fixed effect.

III. RESULTS AND DISCUSSION

As showed in Fig. 1, lactate levels were high at unloading, dropped after resting in the lairage pen ($P < 0.001$), regardless of the resting time, and increased prior to stunning and at slaughter ($P < 0.001$).

The increase in lactate concentration between LA and RE reflects a progressively higher level of muscle activity and stress as the animals are handled from a free-moving group situation to a single line of aligned and restrained individuals. Compared to G2, G1 pigs presented greater lactate levels at EX1 (5.7 vs. 5.2; $P = 0.009$), which may reflect the difference in re-uptake of lactate in animals that have been rested vs. animals that did not have the chance to reduce their metabolic activity, uptake being less in the overnight lairage situation.

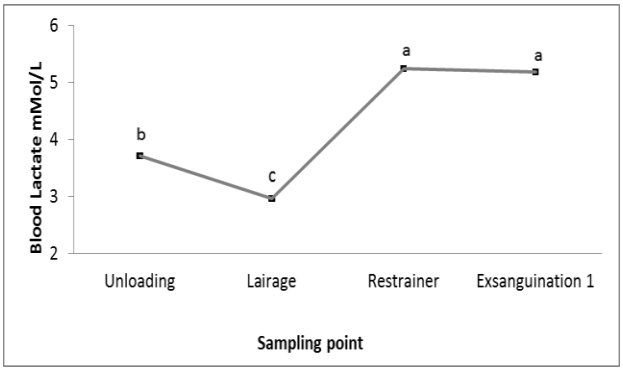

Figure 1. Preslaughter variation of lactate levels (mMol/L; SEM= ± 0.029) in blood collected at various sampling points on the distal ear veins. Between sampling points, means with a different letter differ significantly ($P < 0.001$).

In this study, overnight lairage resulted in a greater pHu in the LD ($P = 0.04$), SM ($P = 0.002$) and AD ($P = 0.02$) muscles, lower L* value in the LD ($P = 0.005$) and SM ($P = 0.008$) muscles, and the lower drip loss value in the LD ($P = 0.01$) and SM ($P = 0.02$) muscles (Table 1).

Table 1. Variation of meat quality characteristics by lairage group[1]

	G1 (135)	G2 (157)	SEM	*P*
LD muscle				
pHu	5.74	5.70	0.02	0.04
L*	51.3	52.4	0.30	0.005
Drip loss, %	2.66	3.26	0.25	0.01
SM muscle				
pHu	5.92	5.85	0.02	0.002
L*	49.5	50.3	0.35	0.008
Drip loss, %	1.92	2.4	0.11	0.02
AD muscle				
pHu	6.13	6.06	0.02	0.02

[1] G1= Group kept in lairage overnight; G2 = Group kept in lairage between 2 and 3 h.

Spearman correlations between blood lactate concentration at different sampling points and meat quality traits, and also between sample points amongst themselves, are shown in Table 2. The greatest correlation was found between blood lactate level at the end of the resting period in the lairage pen (LA) and the pHu value in the SM and AD muscles (r = 0.40; P < 0.001). This relationship indicates that a greater lactate level in blood after a resting period corresponds to a higher pHu value in the ham. AD muscle pHu was also significantly correlated (r = 0.31; P < 0.001) with RE lactate levels. The second highest relationship was found between EX2 lactate and pH1 in the SM muscle (r = -0.39; P < 0.001). The correlation between these two parameters is slightly higher than the one reported using the LD muscle as meat quality indicator (r = 0.32) in a previous study [4]. The relatively high correlation between RE and EX2 lactate levels (r = 0.60; P < 0.001) indicates that the physiological status of pigs at the entrance into the restrainer is a good indicator of the lactate levels found at exsanguination.

Table 2. Spearman correlations between blood lactate levels at different sampling points and meat quality characteristics, and also between sampling points[1]

	UN	LA	RE	EX1	EX2
LD muscle					
pHu	0.11*	0.28***	0.14*	0.08	0.09
L*	-0.07	-0.19*	0.00	0.10	0.14*
Drip loss, %	-0.17*	-0.16*	-0.02	-0.05	0.08
SM muscle					
pH1	-0.13*	0.07	-0.03	-0.18*	-0.39***
pHu	0.29*	0.40***	0.16*	0.18*	0.10
L*	-0.21***	-0.18***	-0.07	-0.01	0.12*
Drip loss, %	-0.24***	-0.27***	-0.09	-0.04	0.08
AD muscle					
pHu	0.28***	0.40***	0.31***	0.28***	0.20***
Sampling points					
UN	1.00	0.20***	0.16***	0.18***	0.22***
LA		1.00	0.45***	0.39***	0.23***
RE			1.00	0.67***	0.60***
EX1				1.00	0.75***
EX2					1.00

UN = Unloading, LA= End Lairage, RE = restrainer, EX1: exsanguination (ear), EX2: exsanguination (bleeding wound); *P<0.05, ***P<0.001.

IV. CONCLUSIONS

Overall, the results of this study suggest that the unloading procedure is stressful for pigs due to an intense muscular activity resulting in great physical fatigue. Likewise, a long resting time may result in muscle fatigue and consequently in greater blood lactate concentration, which could be due to increased opportunities for fighting. Greater blood lactate concentration appears to result in poor pork quality characteristics.

The LSA proved be a tool, which provides a measure that reliably reflects the physiological condition of pigs in the *peri-mortem* phase, especially at exsanguination. When the measure is taken just after lairage and at exsanguination, the observed blood lactate variation may explain the pH variation in pork meat as measured in the ham muscles.

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