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The relationship between exsanguination blood lactate concentration and carcass quality in slaughter pigs

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ABSTRACT

A group of 128 cross-bred barrows were used to determine the relationship between exsanguination blood lactate concentration ([LAC]) and carcass quality following commercial marketing conditions. After 10 h of feed withdrawal, pigs were loaded on a truck with a hydraulically lifted second deck and transported approximately 1 h to the slaughter facility. Pigs were rested for 8 h and stunned with carbon dioxide. Blood lactate concentration was measured on exsanguination blood. Fourteen pork quality measurements were obtained following normal post-mortem processing. Pearson correlations were used to determine the relationships between [LAC] and the meat quality parameters. Exsanguination blood lactate concentration ranged from 4 to 19.7 mM. Higher lactate was associated with lower 60 min pH ($P = 0.0004$) and higher drip loss ($P = 0.02$). These results suggest that under low-stress loading and standard marketing conditions, exsanguination [LAC] is predictive of the rate of early post-mortem metabolism.

1. Introduction

Increases in blood lactate concentration ([LAC]) associated with pre-slaughter stresses such as aggressive handling immediately prior to stunning have been shown to have detrimental effects on pork quality (Hambrecht, Eissen, Newman, Smits, den Hartog, et al., 2005; Hambrecht, Eissen, Newman, Smits, Verstegen, et al., 2005; Hambrecht, Eissen, Nooijen, et al., 2004; Warriss, Brown, Adams, & Corlett, 1994). Pre-slaughter stressors and use of the electric prod to move pigs through the slaughter facility can have a detrimental effect on ultimate pork quality (D'Souza, Dunshea, et al., 1998; Moss, 1984). Hambrecht, Eissen, Nooijen, et al. (2004) determined that swine exposed to aggressive handling just prior to stunning had a higher [LAC] at slaughter and exhibited pork with higher drip loss and thus proposed that [LAC] was a potential indicator of both the physical and psychological stress associated with the handling of pigs immediately before slaughter. Although [LAC] was partially predictive of this decrease in meat quality, the effect of high [LAC] was compounded by high muscle glycolytic potential indicating the complexity of determining ultimate pork quality. Warriss (1994) has demonstrated that pork from pigs stressed immediately before slaughter had less acceptable eating quality than that from pigs handled carefully, despite there being no difference in the predictors of quality that were measured. Warriss et al. (1994) were able to demonstrate a relationship between the subjective assessment of stress level and the objective measures of stress and meat quality in a survey study of swine slaughter facilities. High stress was associated with high exsanguination [LAC] and lower meat quality, i.e. decreased water holding capacity and lighter color. Even though [LAC] exhibited a strong relationship with subjective levels of stress and with meat quality across slaughter facilities, the study was not designed to study the relationship on an individual pig basis. Thus it was not possible to relate the stress experienced by an individual pig at slaughter to its subsequent meat quality (Warriss et al., 1994). Therefore, the objective of this study was to determine the relationship between exsanguination [LAC] and meat quality in individual pigs that experienced low-stress loading at the farm and standard transport, lairage and handling procedures.

2. Materials and methods

Prior to the initiation of these experiments, all animal use, handling, and sampling techniques described herein were approved by the Colorado State University Animal Care and Use Committee.

2.1. Animals, housing and feeding

Sixteen pens of eight (128) cross-bred barrows were used. The pigs used were a cross between a Topigs Tempo boar and a Topigs

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C40 sow (Topigs International, Netherlands). All animals used originated from the same farrowing unit. Barrows were housed in a partially slatted finishing facility typical of the ones used in commercial practice in the local area (Quebec, Canada). Complete pens of test pigs were selected based on the following criteria: structurally sound, healthy and subjective average live weight. Animals in each test pen were identified by a unique numbered plastic ear tag. On the day before slaughter, a unique carcass tattoo number was applied to each pig to facilitate identification at the slaughter facility. Each pen was 8 m^2 with eight test pigs in each pen (stocking density = 1 m^2/pig). There was one feeder and one waterer per pen. Pigs were provided with *ad libitum* feed and water. The pigs used in this study were part of two prior feeding trials. The initial trial compared diets with varying amounts of starch. The second trial compared a low (121 meq/kg) or high (375 meq/kg) dietary electrolyte balance diet. These diets were fed for 3 days prior to slaughter. All diets were formulated with 10 ppm Paylean® for the last 28 days prior to slaughter. When animals were reassigned to the second trial, it was determined that blood parameters were statistically similar across new treatment groups.

2.2. Pre-slaughter handling

Approximately 10 h prior to transport, feed was withdrawn from all test pens with *ad libitum* access to water. Loading was low-stress (no ramps were used); the pigs were moved from the barn to the truck on a flat angle loading chute (width = 0.89 m; length = 3.35 m). The trailer was a straight deck with two decks. The stocking density was approximately 0.45 m^2 per pig. There were no internal ramps within the trailer between decks; a hydraulic lift raised the floor of the trailer to create the second deck. Electric prods were not used during loading or unloading. After loading, pigs were transported approximately 1 h to the slaughter facility. They were rested at the slaughter facility for 8 h. Following lairage, the pigs were stunned with a CO_2 system that had been modified by plant management to eliminate pigs waiting in a single file race. Groups of three pigs were moved into the CO_2 stunner. Handling was low-stress and less than 5% of the pigs were handled with electric goad. Following exsanguination, carcasses entered normal post-mortem processing.

2.3. Blood sampling

An exsanguination blood sample was collected from each pig in a collection vessel (100 ml plastic cup) following carbon dioxide stunning. The blood was immediately transferred to potassium oxalate sodium fluoride tubes to inhibit further glycolytic metabolism (Catalog #: 02-688-48, Fisher Scientific, Pittsburgh, PA). After collection, lactate was measured in blood samples using a hand-held lactate analyzer (Lactate Scout, EKF Diagnostic, Magdeburg, Germany). The lactate analyzer was tested with a standard solution to ensure accuracy (C.V. was 2.8%). The coefficient of variation reported by the analyzer manufacturer is 3–8% dependent on the concentration being measured. The hand-held lactate analyzer was compared to a laboratory procedure, i.e. collection of blood in potassium oxalate sodium fluoride tubes and subsequent analysis of the plasma using immobilized enzyme technology with lactate oxidase on an YSI 2700 Select Biochemistry Analyzer (YSI Incorporated, Life Sciences, Yellow Springs, Ohio). Thirty-nine blood samples were tested to assess agreement between methods. The values obtained between methods were highly correlated ($r = 0.97$, $P = 0.0001$). The mean [LAC] using the hand-held analyzer was lower compared to using an enzymatic procedure with potassium oxalate sodium fluoride plasma (7.4 ± 3.2 and 9.5 ± 4.1, respectively; mean ± SD, mM).

2.4. Carcass measurements

The following measures were recorded on all test pigs by the slaughter facility: hot carcass weight (HWT) and dressing percent, cold carcass weight (CWT) and dressing percent. Cold carcass weight of each pig was recorded approximately 22 h after slaughter, following removal of the head and some internal fat. The carcass was then split into two sides. The right side of the carcass was used for meat quality evaluation.

2.5. Meat quality measurements

Muscle temperature and pH were taken at the third/fourth last rib at 60 min post-mortem approximately 20 min after carcasses were moved into the chill cooler. Muscle pH and temperature were measured with a pH meter (Oakton Instruments Model pH 100 Series, Nilis, IL) with a spear type electrode (Cole Parmer Instrument Company, Vernon Hills, IL) and an automatic temperature compensation probe. At approximately 22 h post-mortem, chilled carcasses were transported to a carcass processing facility and fabricated into wholesale cuts. The loin from each test carcass was removed from the fabrication line and a 2 cm loin chop was taken at the third/fourth last rib from each carcass for the following measurements: 24 h pH and temperature, subjective muscle color (Japanese Color Standards; 1 = pale to 6 = dark color) (Nakai, Saito, Ikeda, Ando, & Komatsu, 1975), objective color (Minolta L^*, a^*, b^* values), 48 h drip loss and marbling (1 = devoid, 10 = abundant) (NPPC., 2000). Firmness was assessed visually using a subjective scale of 1–3 made by a smooth pressure with the finger on the loin eye (1 = firm (ideal consistency) – meat in the loin eye is consistent (hard) and keeps shape; 2 = medium (firm-soft) – meat is softer and the shape is not thoroughly kept; 3 = soft (poor consistency) – meat in the loin eye is too soft and the meat in the loin does not keep the shape). Minolta color was measured with a Minolta Chromameter CR 300 (Minolta Canada, Missisanga, Ontario, Canada) with a D65 light source with a 0° viewing angle geometry. Drip loss was determined using the procedure reported by Correa, Methot, and Faucitano (2007). Drip loss was conducted in triplicate using three muscle cores taken with a 25 mm diameter cork borer. Each core was weighed and placed into a plastic container (Christensen Aps Industrivaengetand, Hilleroed, Denmark). The containers were stored at 4 °C and after 48 h the samples were removed, carefully dabbed and weighed. Drip loss was calculated by determining the difference between the initial and final weight of each muscle core.

The remainder of the chops were packaged and frozen at −80 °C for glycolytic potential determination. Glycolytic potential was calculated using the following equation (Monin & Sellier, 1985): lactate concentration + 2(glucose + glucose-6-phosphate + glycogen). The extraction protocol of (Bergmeyer, 1974) was followed. Briefly, samples were homogenized in buffer with amyloglucosidase (Catalog #: A1602, Sigma Aldrich, St. Louis, MO) to hydrolyze glycogen to glucose. Lactate concentration in the homogenized samples was determined using an enzymatic procedure with lactate dehydrogenase (Catalog #: K607-100, Biovision, Inc., Mountain View, CA) and glucose concentration (glycogen plus free glucose) was determined using a glucose oxidase procedure (Catalog #: 10009582, Cayman Chemical Company, Detroit, MI). The amount of glucose-6-phosphate in the muscle homogenates was negligible and therefore was not included in the analysis. The samples were analyzed on a BioTEK Synergy II plate reader (BioTek Instruments Incorporated, Winooksi, VT).

2.6. Statistical analysis

Pearson correlations were performed using SAS 9.1 (SAS Institute, Cary, NC) to determine relationships between exsanguination