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Effects of handling intensity and live weight on blood acid-base status in finishing pigs

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ABSTRACT: The objective of this study was to determine the effect of live weight on the plasma acid-base response of pigs subjected to various handling intensities. Eighty pigs (equal numbers of barrows and gilts) were used in a completely randomized block design with a $2 \times 2 \times 2$ factorial arrangement of the following treatments: 1) live weight (light [104 kg] vs. heavy [128 kg]), 2) handling intensity (low vs. high), and 3) gender (barrows vs. gilts). Before the handling test, pigs were weighed, venous blood samples were taken to establish baseline levels, and rectal temperature was measured. Pigs were allowed to rest for 2 h before being subjected to the handling treatments, which consisted of moving the pigs through a course (12.2 m long × 0.91 m wide), for a total of eight laps. Animals on the high-intensity treatment were moved rapidly through the course and subjected to a total of 16 single shocks (two shocks per lap) with an electric livestock goad, whereas pigs on the low-intensity treatment were moved at their own pace using a moving panel and a paddle. Rectal temperature and a venous blood sample were taken immediately after handling and at 2 h after handling. Blood plasma was assayed for pH, partial pressure of carbon dioxide (PCO_2), partial pressure of oxygen (PO_2), saturated oxygen (SO_2), total carbon dioxide (TCO_2), bicarbonate (HCO_3), base excess, and lactate. Live weight had no effect on the baseline measurements. After handling, light pigs had higher ($P < 0.05$) blood SO_2 (65.6 vs. $57.2 \pm 2.80\%$) and showed a greater ($P < 0.05$) increase in PO_2 from baseline to post-handling than heavy pigs (15.6 vs. 8.3 ± 2.63 mmHg). Post-handling, pigs on the high- compared with the low-intensity handling treatment had greater ($P < 0.001$) lactate (19.1 vs. 4.9 ± 0.56 mmol/L) and PO_2 (51.6 vs. 36.5 ± 2.44 mmHg) with lower ($P < 0.001$) TCO_2 (18.6 vs. 34.7 ± 0.64 mmol/L), pH (7.02 vs. 7.36 ± 0.015), HCO_3 (16.7 vs. 33.0 ± 0.62 mmol/L), and base excess (–14.2 vs. 7.5 ± 0.75) values. There were no effects of gender on blood measurements or rectal temperatures. Results from this study highlight a major effect of pig handling intensity, a limited effect of live weight, and no effect of gender on blood acid-base responses to handling.

Key Words: Acid-Base Balance, Handling, Live Weight, Stressor

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Introduction

Stress associated with handling of slaughter weight pigs has been shown to increase the number of dead and downer animals (that are unable to rise or walk, sustain an injury, or show signs of exhaustion; Bertol et al., 2002a; Ivers et al., 2002a,b) and can also decrease pork quality (Hambrecht et al., 2003). In pigs, physical exercise and psychological or emotional stress not only trigger responses through both the voluntary and autonomic nervous systems (Stephens and Perry, 1990), but also cause a pronounced metabolic acidosis (Muylle et al., 1968). Metabolic acidosis is characterized by changes in blood parameters, including increased lactic acid, decreased bicarbonate, and a corresponding decrease in blood pH (Bhagavan, 1992). Bertol et al. (2002a,b) reported that pigs subjected to a handling treatment that included the use of electric goads showed an increase in rectal temperature, blood lactate, and the partial pressure of carbon dioxide (**PCO_2**), and a decrease in blood pH compared with before-handling levels. In severe cases, the increase in body temperature and production of lactic acid and CO_2 in the muscles and blood stream is associated with significant physical impairment, and eventually death (Tarrant, 1993). Slaughter weights for pigs continue to increase in most countries, and there is little information available on the relationship between live weight and response to handling. In theory, heavier pigs may show a greater metabolic response and increase in rectal temperature

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as a response to preslaughter handling. Therefore, the objective of this study was to evaluate the effect of two handling intensity treatments in heavy- and lightweight barrows and gilts on blood acid-base measurements and body temperature.

Materials and Methods

Experimental Design and Treatments. The study was carried out as a randomized block design with treatments in a $2 \times 2 \times 2$ factorial arrangement: 1) live weight (light [104 kg] vs. heavy [128 kg]), 2) handling intensity (low vs. high), and 3) gender (barrows vs. gilts). The protocol for this study was approved by the Institutional Animal Care and Use Committee, University of Illinois.

Animals. A total of 80 pigs (progeny of Line 337 sires mated to C22 dams; PIC U.S.A., Franklin, KY) consisting of equal numbers of barrows and gilts was used in the study. The study was carried out in four blocks over time with 20 animals in each block. Within a block, pigs were randomly allotted to treatments on the basis of sex, weight, and sire.

Housing and Feeding. For a 28-d period before the handling test, pigs were housed in a mechanically ventilated building at the University of Illinois Swine Research Center that had part-solid, part-slotted floors. Animals were kept in pens of five pigs at a floor space allowance of 0.94 m^2/pig, and had ad libitum access to a standard corn/soybean meal finisher diet (as fed; 16.0% CP, 0.83% lysine, and 3,176 kcal ME/kg) from a single-space feeder, and to water from a nipple waterer in each pen.

Handling Test. At 0600 on the day of the handling test, rectal temperature was taken and a venous blood sample was collected to establish baseline measurements. Rectal temperature was recorded (to 0.1°C) with an M500HPDT digital thermometer (GLA Agricultural Electronics, San Luis Obispo, CA). Venous blood samples were collected via jugular venipuncture into 3-mL sodium lithium heparinized vacuum tubes (Becton Dickinson, Franklin Lakes, NJ). Animals were restrained using a snout snare during the blood collection process. Care was taken to collect only venous blood. Within 10 min of sampling, blood was assayed for pH, PCO_2, partial pressure of oxygen (**PO_2**), saturated oxygen (**SO_2**), total carbon dioxide (**TCO_2**), bicarbonate (**HCO_3**), base excess, and lactate using an i-STAT Clinical Analyzer and CG4+ cartridges (i-STAT Corp., Princeton, NJ). Following the collection of baseline measurements, pigs were weighed and moved into clean pens. Each pen of pigs was given 2 h to recover from the process of collecting baseline measures before being subjected to the handling test. Measurements of rectal temperature and other blood variables were repeated at 0 and 2 h posthandling as previously described.

Individual pigs were moved from the pen to the handling course and then through the course for a total of eight laps. The handling course was 12.2 m long × 0.91 m wide, with solid walls and an area for the pigs to turn at each end. One lap was defined as the pig passing once in each direction through the course. Pigs subjected to the high-intensity handling treatment were moved through the handling course using an electric goad and a moving panel. Each pig was subjected to a single short-duration shock (approximately 0.5 s) from the goad at the beginning of each pass through the model, for a total of 16 shocks (two per lap). Pigs on the low-intensity treatment were moved using a paddle and a moving panel and each pig was allowed to move at their own pace. If the pig stopped moving it was gently tapped with the paddle or bumped with the panel to reinitiate movement.

Statistical Analysis. The PROC MIXED procedure of SAS (SAS Inst., Inc., Cary, NC) was used to analyze data, with the individual pig as the experimental unit. The model used included the effects of live weight, handling intensity, gender, replicate, block, and two- and three-way interactions. Least squares means were evaluated using the PDIFF and STDERR options of SAS.

Results and Discussion

There were no treatment interactions for any of the traits measured; therefore, only the main effect means are presented.

There were no effects of live weight or gender on baseline measurements (Table 1). Hamilton also reported no effects of gender on baseline blood acid-base levels. Furthermore, baseline values for lactate, pH, HCO_3, and base excess in this study were similar to the values obtained in other studies that collected blood samples from pigs using either indwelling jugular catheters (van der Wal et al., 1986; Bickhardt and Wirtz, 1987) or jugular venipuncture (Haydon et al., 1990; Bertol et al., 2002a,b). This suggests that jugular venipuncture produces blood acid-base values that are similar to those of other sampling methods.

There was no effect of gender on blood acid-base measurements or rectal temperature taken immediately posthandling (Table 2). Other studies have also reported limited differences between barrows and gilts in blood acid-base measures after handling (Hamilton, 2002). In addition, live weight had only limited effect on the measurements taken immediately posthandling (Table 2). Light pigs had greater posthandling SO_2 ($P < 0.01$) and PO_2 ($P < 0.05$) (Table 2) and showed a greater ($P < 0.05$) increase in PO_2 and SO_2 from baseline to immediately posthandling (Table 3) compared with heavy pigs. These results indicate that light pigs absorbed more oxygen and/or consumed less oxygen during handling than heavy pigs. However, there were no other effects of live weight and the differences that existed between heavy and light pigs were relatively small, suggesting a limited impact of live weight across the range evaluated in this study on the response to handling. These results suggest no additional handling-related problems at slaughter weights above the average levels currently used in most countries.

Table 1. Least squares means for the effects of live weight and gender on baseline values for blood plasma measurements and rectal temperature

	Live weight (LW)[a]		Gender			*P*-value	
Variable	Light	Heavy	Barrow	Gilt	SE	LW	Gender
No. of animals	40	40	40	40			
Lactate, mmol/L	3.1	2.8	3.1	2.7	0.29	0.58	0.34
TCO_2, mmol/L[b]	36.9	36.8	36.9	36.8	0.36	0.91	0.94
PH	7.36	7.38	7.36	7.37	0.008	0.17	0.37
PCO_2, mmHg[b]	62.4	59.9	61.9	60.3	1.36	0.21	0.41
PO_2, mmHg[b]	30.9	33.7	32.9	31.8	1.39	0.17	0.59
HCO_3, mmol/L	34.9	35.0	34.9	35.0	0.35	0.82	0.87
Base excess, mmol/L	9.5	9.8	9.6	9.8	0.37	0.56	0.73
SO_2, %[b]	53.3	57.5	54.7	56.1	2.20	0.18	0.64
Rectal temperature, °C	38.9	39.1	39.0	39.0	0.06	0.09	0.94

[a]Light = 104 kg, heavy = 128 kg.
[b]TCO_2 = total carbon dioxide, PCO_2 = partial pressure of carbon dioxide, PO_2 = partial pressure of oxygen, HCO_3 = bicarbonate, SO_2 = saturated oxygen.

Table 2. Least squares means for the effects of live weight, handling intensity, and gender on blood plasma measurements and rectal temperature collected immediately posthandling

	Live weight (LW)[a]		Handling intensity (HI)		Gender			*P*-values		
Variable	Light	Heavy	Low	High	Barrow	Gilt	SE	LW	HI	Gender
No. of animals	40	40	40	40	40	40				
Lactate, mmol/L	12.1	12.0	4.9	19.1	12.0	12.1	0.56	0.89	0.001	0.91
TCO_2, mmol/L[b]	26.3	27.0	34.7	18.6	27.1	26.2	0.64	0.41	0.001	0.36
pH	7.20	7.18	7.36	7.02	7.19	7.18	0.015	0.38	0.001	0.77
PCO_2, mmHg[b]	60.6	63.9	60.4	64.1	62.3	62.2	2.35	0.33	0.26	0.97
PO_2, mmHg[b]	46.5	41.5	36.5	51.6	43.9	44.1	2.44	0.15	0.001	0.97
HCO_3, mmol/L[b]	24.5	25.2	33.0	16.7	25.2	24.5	0.62	0.39	0.001	0.41
Base excess, mmol/L	–3.6	–3.2	7.5	–14.2	–2.9	–3.8	0.75	0.72	0.001	0.42
SO_2, %[b]	65.6	57.2	61.0	61.8	61.8	60.9	2.8	0.04	0.85	0.84
Rectal temperature, °C	39.7	39.8	39.7	39.8	39.8	39.7	0.06	0.43	0.06	0.79

[a]Light = 104 kg, heavy = 128 kg.
[b]TCO_2 = total carbon dioxide, PCO_2 = partial pressure of carbon dioxide, PO_2 = partial pressure of oxygen, HCO_3 = bicarbonate, SO_2 = saturated oxygen.

Table 3. Least squares means for the effects of live weight, handling intensity, and gender on the change in blood plasma measurements and rectal temperature between baseline and immediately posthandling

	Live weight (LW)[a]		Handling intensity (HI)		Gender			*P*-value		
Variable	Light	Heavy	Low	High	Barrow	Gilt	Avg SE	LW[b]	HI	Gender
No. of animals	40	40	40	40	40	40				
Change in values[b]										
Lactate, mmol/L	8.9	9.1	1.9	16.2	8.89	9.3	0.53	0.81	0.001	0.47
TCO_2, mmol/L[c]	–10.6	–10.0	–2.7	–17.9	–10.1	–10.6	0.73	0.59	0.001	0.63
pH	–0.16	–0.20	–0.02	–0.35	–0.17	–0.19	0.015	0.08	0.001	0.51
PCO_2, mmHg[c]	–1.8	3.8	–2.0	4.0	0.2	1.8	2.36	0.10	0.08	0.62
PO_2, mmHg[c]	15.6	8.3	6.2	17.8	11.6	12.3	2.63	0.05	0.003	0.86
HCO_3, mmol/L[c]	–10.4	–10.0	–2.6	–17.8	–10.0	–10.5	0.68	0.69	0.001	0.61
Base excess, mmol/L	–13.1	–13.3	–2.8	–23.6	–12.9	–13.6	0.79	0.83	0.001	0.56
SO2, %[c]	12.3	0.3	8.3	4.4	7.9	4.8	3.29	0.01	0.40	0.51
Rectal temperature, °C	0.7	0.8	0.7	0.9	0.8	0.8	0.07	0.35	0.02	0.80

[a]Light = 104 kg, heavy = 128 kg.
[b]Change = baseline value minus posthandling value.
[c]TCO_2 = total carbon dioxide, PCO_2 = partial pressure of carbon dioxide, PO_2 = partial pressure of oxygen, HCO_3 = bicarbonate, SO_2 = saturated oxygen.

Table 4. Least squares means for the effects of live weight, handling intensity, and gender on blood plasma measurements and rectal temperature collected 2 h posthandling

	Live weight (LW)[a]		Handling intensity (HI)		Gender			*P*-values		
Variable	Light	Heavy	Low	High	Barrow	Gilt	Avg SE	LW[a]	HI	Gender
No. of animals	40	40	40	40	40	40				
2 h posthandling values										
Lactate, mmol/L	2.9	3.1	2.0	4.0	3.0	3.0	0.37	0.75	0.001	0.88
TCO_2, mmol/L[b]	34.5	34.8	35.3	34.0	34.8	34.5	0.36	0.63	0.009	0.67
pH	7.40	7.40	7.41	7.39	7.41	7.40	0.010	0.89	0.18	0.34
PCO_2, mmHg[b]	53.5	53.4	53.4	53.4	52.7	54.1	1.35	0.95	1.00	0.49
PO_2, mmHg[b]	32.1	31.7	32.1	31.7	33.0	30.8	1.22	0.83	0.84	0.22
HCO_3, mmol/L[b]	32.9	33.1	33.7	32.4	33.0	33.0	0.34	0.64	0.008	0.84
Base excess, mmol/L	8.1	8.3	9.1	7.3	8.4	8.0	0.37	0.59	0.002	0.44
SO_2, %[b]	58.6	56.9	58.3	57.3	59.8	55.8	2.48	0.64	0.78	0.26
Rectal temperature, °C	39.1	39.1	39.1	39.1	39.1	39.1	0.07	0.58	0.89	0.59

[a]Light = 104 kg, heavy = 128 kg.
[b]TCO_2 = total carbon dioxide, PCO_2 = partial pressure of carbon dioxide, PO_2 = partial pressure of oxygen, HCO_3 = bicarbonate, SO_2 = saturated oxygen.

Handling intensity had a major effect on blood acid-base balance immediately posthandling (Table 2) but did not result in any downer animals (defined as pigs that were unable to rise or walk, sustained an injury, or showed signs of exhaustion). Pigs subjected to the high-intensity treatment had greater ($P < 0.001$) lactate and PO_2 with correspondingly lower ($P < 0.001$) TCO_2, pH, HCO_3, and base-excess values than pigs on the low-intensity treatment (Table 2). Furthermore, there was a tendency for pigs on the high-intensity treatment to have a higher ($P = 0.06$) posthandling rectal temperature than those on the low-intensity handling treatment. In addition, with the exception of blood lactate, PCO_2, and SO_2 levels, changes in blood measures and rectal temperature from baseline to posthandling were greater ($P < 0.05$) for the high- than for the low-intensity treatment (Table 3).

Several studies have reported changes similar to ours in blood acid-base parameters and rectal temperature of pigs subjected to an exercise model or a high-intensity handling treatment (Muylle et al., 1968; van den Hende et al., 1970; Ivers et al., 2002a). For example, van den Hende et al. (1970) used electrical stimulation (alternating current at 200 V for 5 s) to exercise the leg of pigs for 5 min and reported large decreases in venous blood pH (from 7.46 to 6.88) and base excess (from –7.8 to –22.0 mmol/L) with a corresponding increase in lactate (from 7.38 to 40.6 mmol/L). Van der Wal et al. (1986) evaluated five potential stressors (forced standing, placing the pig in a maxillary sling, fixation of the pig with the maxillary sling, prolonged fixation, and fixation with a sling and electrical stimulation), and reported much smaller changes in blood pH (from 7.33 to 7.23), base excess (from 0.48 to –3.27 mmol/L), and lactate (from 1.45 to 3.84 mmol/L) from resting to poststress. However, other studies that have employed a high-intensity animal handling treatment similar to that used in the current study have reported similar changes in blood pH, lactate, bicarbonate, base excess, PO_2, and PCO_2 (Bertol et al., 2002a,b). Alterations in blood acid-base levels from resting to posthandling have been shown to be proportional to the intensity and duration of the stressful stimulus and normally result in a change to an acidotic state (van der Wal et al., 1986; Bertol et al., 2002a). Thus, variation among studies in the extent of changes in blood gasses are likely due to differences in either the intensity and/or the duration of the stressor. Furthermore, Heinze and Mitchell (1989) showed that physical exertion, in the form of a treadmill exercise, produced a metabolic response in pigs that was similar to that observed in the current study as a result of high-intensity handling. Jorgensen and Hyldgaard-Jensen (1975) demonstrated that pigs trained and exercised regularly on a treadmill did not show the blood lactate response that untrained pigs produced the first time that they were exercised on the treadmill. Thus, it is evident that physical exercise and conditioning play a role in determining the extent of lactate production during handling. The pigs used in the present research had been regularly handled and moved before the start of the study but had not been exposed to any formal exercise regimen.

There were no effects of live weight or gender on blood acid-base parameters or rectal temperature when measured 2 h posthandling (Table 4). However, pigs on the high-intensity handling treatment had greater ($P < 0.05$) blood lactate and correspondingly lower blood TCO_2, HCO_3, and base excess when compared with pigs on the low-intensity handling treatment (Table 4). Nonetheless, the differences between the handling treatments at 2 h posthandling were much less than immediately posthandling, and all measures were generally similar ($P > 0.05$) to the baseline values (Tables 1 and 4). These results suggest that a 2-h rest after low-intensity handling may be adequate for blood acid-base status to return to normal; however, if pigs are handled more intensely, then more time is required for blood acid-base levels to return to resting values. The

results of the current study are similar to those of Bertol et al. (2002a), who found that acid-base levels of pigs subjected to high-intensity handling had returned to baseline levels by 2 h posthandling. In addition, Jorgensen and Hyldgaard-Jensen (1975) showed that blood lactate levels in pigs subjected to exercise on a treadmill had returned to the normal baseline level within 45 min posthandling. Differences between studies in the length of time before blood parameters return to baseline levels after exercise may, in part, be related to the severity and/or duration of the handling procedures, as well as the particular exercise model tested.

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