A Multidisciplinary Approach to Assess the Welfare of Weaned Pigs During Transport at Three Space Allowances

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A Multidisciplinary Approach to Assess the Welfare of Weaned Pigs During Transport at Three Space Allowances

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Pork Industry Institute, Department of Animal and Food Sciences, Texas Tech University

Transport can be a stressful experience for pigs, especially in pigs simultaneously experiencing weaning stress. The objective of this study was to use a multidisciplinary approach to assess the welfare of weaned pigs during transport at 3 space allowances. A commercial semitrailer, fitted with compartments, provided 0.05, 0.06, and 0.07 m²/pig. The study recorded frequency of standing, lying, sitting, and standing-rearing on another pig during the entire duration of transport. Blood samples, body weights, and lesion scores were collected from a subset of pigs (n = 48 per space allowance) in each experimental compartment. Transport time for the pigs was 148.0 ± 10.0 min to the wean-to-finishing site. Total white blood cell counts, cortisol, and several blood chemistry values increased (p < .05) after transport regardless of space allowance. Glucose and body weight decreased (p < .05) after transport regardless of space allowance. Space allowance influenced stand-rearing, sitting, standing, and lying behaviors in pigs. Combining behavioral and physiological measures of stress provides a robust picture of piglet welfare during transport at different space allowances.

Transport is a complex stressor consisting of many potentially stressful factors including fluctuating temperatures, stocking density, withdrawal from food and water, mixing with conspecifics, and motion (Lambooj & van Putten, 1993). All

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these stressors have been shown to activate the hypothalamic-pituitary-adrenal axis (HPA) in pigs individually and in combination. The practice of transporting pigs at weaning is becoming more popular in the United States. Transportation has the potential to affect the health and welfare of pigs, especially in pigs already experiencing weaning stress. Weaning in itself is a substantial stressor that can affect the immune response, performance, and behavior of pigs (Hay et al., 2001; Kanitz, Tuchscherer, Tuchscherer, Stabenow, & Manteuffel, 2002).

Most of the literature pertaining to transport stress in pigs has been conducted on market-weight pigs. Transport of market-weight pigs has been shown to increase physiological measures of stress and fatigue such as glucose, lactate dehydrogenase, and creatine phosphokinase concentrations (Barton-Gade & Christensen, 1998; Kim, Woo, & Lee, 2004; Warriss et al., 1998). Space allowance of pigs during transport can further affect the stress response of pigs to transport. Higher stocking densities have been associated with higher mortality rates (Ritter et al., 2004; Warriss, 1998). Lower stocking densities have been associated with unacceptable rates of skin damage (Barton-Gade & Christensen, 1998). Lactate dehydrogenase was lower in pigs transported at low (0.31 m²/100 kg) compared with medium (0.35 m²/100 kg) or high (0.39 m²/100 kg) stocking densities (Kim et al., 2004), and creatine phosphokinase levels were greater in pigs kept at stocking densities lower than 0.5 m²/100 kg during transport (Barton-Gade & Christensen, 1998; Warriss et al., 1998).

Behavior of pigs can also be used as an indicator of welfare in response to transport stress at different space allowances. Berry and Lewis (2001) found that weaned pigs (6.36 ± 0.47 kg), transported at a space allowance of 0.06 m²/pig, spent 55.3% of the time resting and 40.5% of the time standing during transport. Kim et al. (2004) found that there was less standing behavior during transport at low (0.39 m²/100 kg) compared with medium (0.35 m²/100 kg) and high (0.31 m²/100 kg) stocking density rates. However, Barton-Gade and Christensen (1998) did not find that giving pigs more space resulted in more lying behavior; on the contrary, they observed continuous disturbances from other pigs. In addition, they found that, with more space, pigs had more difficulty maintaining their balance.

Transport stress at different space allowances has been shown to influence several physiological and behavioral welfare measures in pigs, but few studies have compared both physiological and behavioral measures in the same study. Furthermore, the effect of transport stress on weaned pigs transported at different space allowances has not been extensively reported in the literature. The objective of this study was to measure the stress response of weaned pigs during transport using a multidisciplinary approach including immunology, physiology, and behavior to more comprehensively assess the welfare of pigs during transport at three different space allowances.
MATERIALS AND METHODS

Animals, Housing, and Experimental Design

Pigs used in this study were a Landrace, Large White, and Duroc cross. All sows were fed a diet to meet or exceed National Research Council (1998) nutrient requirements, and water was provided ad libitum. All procedures pertaining to the nonhuman animals were approved by the Texas Tech University Animal Care and Use Committee. This study was replicated four times in May 2007 and twice in September 2007. This study was conducted in fall and spring to avoid extreme cold and hot temperatures that could possibly confound the effects of transport and space allowance on the physiological and behavioral response of weaned pigs.

A commercial semitrailer was fitted with experimental compartments that provided 0.05, 0.06, and 0.07 m²/pig. All three experimental compartment sizes were represented on the upper and lower deck of the trailer. The location of the different experimental compartments was the same for all replications. On the top deck, the experimental compartments were organized in the order of nonexperimental compartment, 0.05, 0.06, and then 0.07 square meter compartment. On the bottom deck, the experimental compartments were organized in the order of nonexperimental compartment, 0.07, 0.05, and then 0.06 square meter compartment. One hundred pigs were transported in each experimental compartment, so group size did not confound compartment size.

This study was replicated six times. Only a subset of the 100 pigs was sampled for blood analysis, body weight data, and lesion scores. Four pigs were sampled per experimental compartment. Over the entire study, 144 weight-matched (5.3 ± 0.10 kg) pigs (18 ± 1 day of age) from 24 sows/litters were allocated to one of three space allowances: 0.05 m²/pig, 0.06 m²/pig, and 0.07 m²/pig. Barrows and gilts were represented equally over all space allowances. In total, 48 pigs (24 gilts and 24 barrows) per treatment/compartment size were used.

The initial sample and data collection for this experiment occurred at a gestation-to-weaning facility. Prior to weaning, a blood sample was taken from all experimental pigs; pigs were ear tagged, weighed, lesion scored, and then returned to the farrowing crate until weaning. Skin lesions were scored as 0 (no lesions), 1 (minor), and 2 (severe). Blood samples were taken by placing pigs in a supine position and collecting 5 ml of blood over heparin by anterior vena cava puncture (procedure lasts approximately 1 min) for analysis of hematological, blood chemistry, cortisol, and immune measures.

Approximately 30 min after sampling, all pigs (experimental and nonexperimental pigs) were removed from the farrowing crates and moved into holding pens. Experimental piglets were placed with “filler” pigs so that group size was held constant at 100 pigs per experimental compartment. Male and female
pigs were segregated on different decks of the trailer as is common practice on commercial swine facilities. Pig gender on each deck was alternated so as not to confound trailer deck level with gender effects. Once all pigs were loaded on the trailer, the trailer was transported to the wean-to-finish site. The truck followed the same route for each replication, a travel time of $148.0 \pm 10.0$ min. The trailer was instrumented with HOBO (Onset Computer Corporation, Bourne, MA) data loggers, which were secured to the gate, in between the compartments, slightly above pig height (to prevent pigs from chewing on the data loggers) to measure temperature and humidity. There was one data logger per compartment. Wind speed averaged $1.9 \pm 0.88$ m/s during the entire trip. Temperature inside the trailer ranged from 14.9 to 29.5$^\circ$C during transport with an average temperature of 21.2 $\pm$ 3.25$^\circ$C. Relative humidity inside the trailer ranged from 33.2 to 92.5% with an average relative humidity of 55.6 $\pm$ 10.7%.

At the wean-to-finish site, experimental pigs were located, weighed, lesion scored, and a blood sample collected. Pigs were again held in a supine position and a 10 ml blood sample collected over heparin by anterior vena cava puncture (procedure lasts approximately 1 min) for analysis of hematological, blood chemistry, cortisol, and immune measures.

**Blood Analysis**

Whole blood (before and after transport) was analyzed to determine white blood cell counts, differential leukocyte counts, hemoglobin, and hematocrit concentrations (Cell-Dyn® 1800, Abbott Laboratories, Abbott Park, IL); the granulocyte-to-lymphocyte ratio was calculated by dividing the percentage of neutrophils by the percentage of lymphocytes. Blood samples were centrifuged and plasma collected for analysis of cortisol concentrations and blood chemistry measures. Cortisol concentrations were analyzed using an enzyme immunoassay kit (Assay Designs, Ann Arbor, MI). Blood chemistry was analyzed using the Roche/Hitachi 912 (Roche Diagnostics, Basel, Switzerland) for blood urea nitrogen (BUN), creatinine, glucose, total protein, albumin, aspartate aminotransferase (AST), creatine kinase (CK), alkaline phosphatase (Alk Phos), gamma-glutamyl transpeptidase (GGT), and total bilirubin.

Neutrophils were isolated from 10 ml of whole blood as described by Hulbert and McGlone (2006). The phagocytosis assay was performed to determine the percentage of latex beads engulfed by neutrophils as previously described (Hulbert & McGlone, 2006). The chemotaxis assay was performed according to published methods (Hulbert & McGlone, 2006; Salak, McGlone, & Lyte, 1993). Briefly, migration of neutrophils across a polyvinylpyrrolidone-free filter (pore size 5 $\mu$m; Neuro Probe) toward media or toward recombinant human complement-C5a (C5a; chemotaxis) was measured.
TABLE 1
Description of Behaviors

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting(^a)</td>
<td>Resting on the caudal part of the body</td>
</tr>
<tr>
<td>Standing(^a)</td>
<td>Assuming or maintaining an upright position on extended legs</td>
</tr>
<tr>
<td>Standing-rearing on top of another pig</td>
<td>Assuming or maintaining an upright position on extended legs while standing on another pig/s</td>
</tr>
<tr>
<td>Lying(^a)</td>
<td>Maintaining a recumbent position</td>
</tr>
</tbody>
</table>


Behavior

Digital still cameras were placed in each experimental compartment to record the behavior and postures of the pigs during transport. Cameras were fastened to the compartment gates, dividing the experimental compartments. All cameras were fastened at the same angle and height so that the area recorded was similar among compartments. The number of pigs recorded per frame differed, depending on the behavior displayed by the pigs (lying vs. standing). Cameras were programmed to take one picture a minute (1-min scan samples). Behaviors measured included lying, standing, sitting, and standing-rearing on top of another pig. Behaviors are described in Table 1. All behaviors were mutually exclusive. The frequency of each behavior was calculated over the entire transport period and divided into five 30-min periods.

Trailer Design

A Wilson brand (Wilson Trailer Company, Sioux City, IA) straight-deck stock trailer was used during all replications of this trial. The trailer was fitted with an upper and lower deck. The trailer contained compartments that were adjusted to provide 0.05, 0.06, and 0.07 m\(^2\)/pig based on pigs weighing approximately 5 kg and with each compartment holding 100 animals. Each of the three space allowances were represented on each of the upper and lower decks of the trailer. The same trailer was used for all replications of this study. Wood shavings were spread over the upper and lower deck prior to the pigs being loaded.

Statistical Analysis

All data were tested for constant variance and departures from normal distribution. Data lacking normality were transformed logarithmically using log\(_{10}\) function. Data were subjected to analysis of variance, using the mixed model
procedure of SAS Version 9.1 (SAS Inst., Inc., Cary, NC). All analyses were performed as two-tail tests.

The trailer was the block with each block containing all treatment groups. The study was a random complete block design with three treatments/space allowances (0.05, 0.06, and 0.07 m$^2$/pig). The main fixed effects were block (6 levels), gender (2 levels), deck (2 levels), treatment (3 levels), and time (2 levels). Random effects in the model were litter (24 levels) and piglet (144 levels). The interaction between treatment and time ($df = 4$) and treatment and deck ($df = 4$) was included in the model. Behavioral data were also analyzed using analysis of variance using the mixed model procedure of SAS. The behavior observation period was divided into five 30-min periods. For behavioral measures, the main fixed effects were block (6 levels), gender (2 levels), deck (2 levels), treatment (3 levels), and period (10 levels). The interaction between treatment and period ($df = 8$) and treatment and deck ($df = 2$) was included in the model.

RESULTS

Cortisol concentrations were higher ($p < .001$) for pigs after transport regardless of space allowance (Table 2). No treatment, gender, deck, treatment*deck, or treatment*time effects were observed for cortisol concentrations ($p > .05$).

Blood urea nitrogen, total bilirubin, total protein, albumin, AST, CK, and GGT were higher ($p < .05$) in pigs after transport regardless of space allowance (Table 2). Conversely, creatinine and glucose concentrations were lower ($p <$

<table>
<thead>
<tr>
<th>Measure</th>
<th>Pretransport</th>
<th>SE</th>
<th>Posttransport</th>
<th>SE</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>72</td>
<td></td>
<td>72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cortisol, ng/ml</td>
<td>41.7</td>
<td>3.87</td>
<td>80.9</td>
<td>5.65</td>
<td>.001</td>
</tr>
<tr>
<td>Glucose, mg/dl</td>
<td>127</td>
<td>1.4</td>
<td>122</td>
<td>1.5</td>
<td>.032</td>
</tr>
<tr>
<td>Blood urea nitrogen, mg/dl</td>
<td>6.4</td>
<td>0.22</td>
<td>8.0</td>
<td>0.23</td>
<td>.001</td>
</tr>
<tr>
<td>Creatine, mg/dl</td>
<td>0.92</td>
<td>0.022</td>
<td>0.85</td>
<td>0.022</td>
<td>.038</td>
</tr>
<tr>
<td>Total bilirubin, mg/dl</td>
<td>0.30</td>
<td>0.018</td>
<td>0.41</td>
<td>0.018</td>
<td>.001</td>
</tr>
<tr>
<td>Total protein, g/dl</td>
<td>5.3</td>
<td>0.04</td>
<td>5.4</td>
<td>0.04</td>
<td>.006</td>
</tr>
<tr>
<td>Albumin, g/dl</td>
<td>3.4</td>
<td>0.04</td>
<td>3.7</td>
<td>0.04</td>
<td>.001</td>
</tr>
<tr>
<td>Aspartate aminotransferase, U/L</td>
<td>50.3</td>
<td>2.63</td>
<td>67.7</td>
<td>2.01</td>
<td>.001</td>
</tr>
<tr>
<td>Creatine kinase, U/L</td>
<td>863</td>
<td>88.9</td>
<td>1,301</td>
<td>76.2</td>
<td>.001</td>
</tr>
<tr>
<td>Alkaline phosphatase, U/L</td>
<td>559</td>
<td>15.8</td>
<td>554</td>
<td>15.7</td>
<td>.819</td>
</tr>
<tr>
<td>Gamma-Glutamyl transpeptidase, U/L</td>
<td>40.2</td>
<td>5.31</td>
<td>87.8</td>
<td>5.31</td>
<td>.001</td>
</tr>
</tbody>
</table>
in pigs after transport regardless of space allowance (Table 2). No treatment, gender, deck, treatment*deck, or treatment*time effects were observed for blood chemistry concentrations \((p > .05)\).

Total white blood cell counts were higher \((p < .001)\) for pigs after transport regardless of space allowance (Table 3). The percentage of lymphocytes were lower \((p < .001)\); conversely, the granulocyte and lymphocyte ratio was higher \((p < .001)\) for pigs after transport regardless of space allowance (Table 3). No treatment, gender, deck, treatment*deck, or treatment*time effects were observed for leukocyte counts \((p > .05)\).

The percentage of latex beads engulfed by neutrophils did not differ \((p > .05)\) among pigs transported at different space allowances \((0.05 \text{ m}^2/\text{pig}: 97.1 \pm 5.15\% ; 0.06 \text{ m}^2/\text{pig}: 87.8 \pm 5.80\% ; 0.07 \text{ m}^2/\text{pig}: 90.7 \pm 5.36\% )\). Chemotaxis in response to the mitogen C5a did not differ \((p > .05)\) among pigs transported at different space allowances \((0.05 \text{ m}^2/\text{pig}: 4.8 \pm 2.56 \text{ cells/5 fields}; 0.06 \text{ m}^2/\text{pig}: 4.7 \pm 2.77 \text{ cells/5 fields}; 0.07 \text{ m}^2/\text{pig}: 5.3 \pm 2.66 \text{ cells/5 fields})\).

Pig body weight was lower \((p < .05)\) after transport regardless of space allowance (before transport: 5.3 \pm 0.07 kg; after transport: 5.1 \pm 0.07 kg). Lesion scores were higher \((p < .001)\) in pigs after transport regardless of space allowance (before transport: 0.12 \pm 0.025; after transport: 0.48 \pm 0.046). No treatment, gender, deck, treatment*deck, or treatment*time effects were observed for body weight or lesion scores \((p > .05)\).

Pigs transported at 0.06 \text{ m}^2/\text{pig} spent less \((p < .001)\) time standing-rearing than pigs transported at 0.05 and 0.07 \text{ m}^2/\text{pig} (Figure 1). Furthermore, barrows spent more \((p < .001)\) time standing-rearing than gilts during transport (barrow: 3.9 \pm 0.15\%; gilt: 3.3 \pm 0.15\%).

Pigs transported at 0.07 \text{ m}^2/\text{pig} spent less time sitting than pigs transported at 0.05 \text{ m}^2/\text{pig} \((p < .05)\), between 31 and 60 and 91 and 150 min, and 0.06 \text{ m}^2/\text{pig} \((p < .06)\), between 91 and 150 min after transport (Figure 2).

TABLE 3

Leukocyte Values of Weaned Pigs Before and After Transport

<table>
<thead>
<tr>
<th>Measure</th>
<th>Pretransport</th>
<th>SE</th>
<th>Posttransport</th>
<th>SE</th>
<th>(P) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(N)</td>
<td>48</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total white blood cell count, (10^3/\mu L)</td>
<td>10.0</td>
<td>0.40</td>
<td>13.3</td>
<td>0.57</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Granulocytes, (10^3/\mu L)</td>
<td>1.3</td>
<td>0.08</td>
<td>1.9</td>
<td>0.14</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Lymphocytes, (10^3/\mu L)</td>
<td>6.4</td>
<td>0.24</td>
<td>5.9</td>
<td>0.24</td>
<td>.115</td>
</tr>
<tr>
<td>Neutrophils, %</td>
<td>13.4</td>
<td>0.67</td>
<td>14.6</td>
<td>0.81</td>
<td>.233</td>
</tr>
<tr>
<td>Lymphocytes, %</td>
<td>65.7</td>
<td>1.05</td>
<td>45.7</td>
<td>1.18</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Granulocyte to lymphocyte ratio</td>
<td>0.21</td>
<td>0.014</td>
<td>0.34</td>
<td>0.028</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>
FIGURE 1 The percentage of time pigs spent standing-rearing when transported at 0.05 m$^2$/pig, 0.06 m$^2$/pig, and 0.07 m$^2$/pig. Least square means accompanied by different subscripts are different at $p < .05$.

FIGURE 2 The percentage of time pigs spent sitting when transported at 0.05 m$^2$/pig (♦), 0.06 m$^2$/pig (■), and 0.07 m$^2$/pig (▲) during a 150-min transport period. At each time period, least square means accompanied by a * signifies that 0.05 m$^2$/pig differs ($p < .05$) from 0.06 m$^2$/pig, # signifies that 0.05 m$^2$/pig differs ($p < .05$) from 0.07 m$^2$/pig, and + signifies that 0.06 m$^2$/pig differs ($p < .06$) from 0.07 m$^2$/pig.
FIGURE 3 The percentage of time pigs spent lying when transported at 0.05 m²/pig (●), 0.06 m²/pig (■), and 0.07 m²/pig (▲) during a 150-min transport period. At each time period, least square means accompanied by an * signifies that 0.05 m²/pig differs (p < .05) from 0.06 m²/pig, # signifies that 0.05 m²/pig differs (p < .05) from 0.07 m²/pig, and + signifies that 0.06 m²/pig differs (p < .05) from 0.07 m²/pig.

Pigs transported at 0.06 m²/pig spent more (p < .05) time lying than pigs transported at 0.07 m²/pig, between 61 and 90 min, and 0.05 m²/pig, between 91 and 120 min after transport (Figure 3). Furthermore, barrows spent less (p < .05) time lying than gilts during transport (barrow: 11.2 ± 0.70%; gilt: 13.5 ± 0.67%).

Pigs transported at 0.06 m²/pig spent less time standing than pigs transported at 0.05 m²/pig (p < .05), between 91 and 120 min, and 0.07 m²/pig (p < .06), between 121 and 150 min after transport (Figure 4). Furthermore, barrows spent more (p < .005) time sitting than gilts during transport (barrow: 79.6 ± 0.72%; gilt: 76.6 ± 0.69%).

DISCUSSION

Transport increased cortisol concentrations and blood chemistry values in weaned pigs. Greater cortisol concentrations and granulocyte to lymphocyte ratios in pigs after transport suggest that these animals experienced stress regardless of space allowance. The granulocyte to lymphocyte ratio and cortisol concentrations were also increased in nursery pigs after a 4 hr transport (McGlone et al., 1993). Transporting pigs at weaning involves a multitude of stressors, including exposure to a novel environment, weaning, mixing, and motion, which have all been shown to activate the HPA axis in pigs (Desautes, Sarrieau, Caritez,
FIGURE 4 The percentage of time pigs spent standing when transported at 0.05 m$^2$/pig (♦), 0.06 m$^2$/pig (■), and 0.07 m$^2$/pig (▲) during a 150-min transport period. At each time period, least square means accompanied by a * signifies that 0.05 m$^2$/pig differs ($p < .05$) from 0.06 m$^2$/pig, # signifies that 0.05 m$^2$/pig differs ($p < .05$) from 0.07 m$^2$/pig, and + signifies that 0.06 m$^2$/pig differs ($p < .06$) from 0.07 m$^2$/pig.

& Mormede, 1999; Hay et al., 2001; Kanitz et al., 2002; Lambooij & van Putten, 1993; McGlone et al., 1993). The experience of transport increased cortisol concentrations and the granulocyte to lymphocyte ratio in weaned pigs; however, neither cortisol nor the granulocyte to lymphocyte was a sensitive enough measure of stress to detect differences in the stress response experienced by pigs transported at different space allowances.

In this study, we were not able to differentiate between the stress response caused by transport and that caused by weaning. Transport and weaning stress individually have been shown to influence the immune response, performance, physiology, and behavior of young pigs (Hay et al., 2001; Kanitz et al., 2002; McGlone et al., 1993). On commercial gestation-to-weaning facilities in the United States, it is common to wean and transport pigs simultaneously. This study was designed to be commercially applicable; therefore, transport and weaning stress were not segregated as pigs will always experience both of these stressors at the same time. However, it would be very interesting to segregate the effects of weaning and transport to determine if these stressors are additive or if the stress response plateaus at a certain point.

Total white blood cells were elevated in pigs after transport regardless of space allowance. This phenomenon is known as leukocytosis and has been shown in people experiencing acute physical or psychological stress (Zorrilla et al., 2001). Changes in lymphocyte numbers in response to either an acute
physical or psychological stressor are thought to be mediated via the activation of $\beta_2$-adrenoceptors; increases in granulocyte numbers are thought to be caused by stimulation of $\alpha$-adrenoceptors (Benschop, Rodriguez-Feuerhahn, & Schedlowski, 1996). Therefore, transport/weaning stress appears to be sufficient to mobilize the immune cells in pigs, which could have long-term consequences on both the health and the well being of pigs after transport. The immune system can be affected by weaning (Kanitz et al., 2002; Orgeur et al., 2001) and mixing (Deguchi & Akuzawa, 1998) in pigs.

In this study, neutrophil function as measured by phagocytosis and chemotaxis was not influenced by space allowance during transport. It was not in the scope of this study to measure the functional immune system in pigs before and after transport. In future studies, it would be interesting to track the immune system of pigs for a period of time after transport to determine if transport and/or weaning are adequate stressors to suppress the immune system and increase disease incidence in young pigs.

Creatine kinase and AST are released from muscle fibers into the bloodstream in response to exercise or tissue damage and are good indicators of physical stress and/or tissue damage in pigs (Fabrega et al., 2002; Yu, Bao, Zhao, & Lv, 2007). Blood urea nitrogen is a waste product in the blood caused from the breakdown of protein. Creatine kinase, AST, and BUN were higher in weaned pigs after transport regardless of space allowance. Creatine kinase concentrations have been shown to increase in slaughter-weight pigs in response to transport stress (Elbers, Visser, Odink, & Smeets, 1991; Fabrega et al., 2002). Furthermore, CK concentrations were shown to increase in market-weight pigs transported at stocking densities lower than 0.5 m$^2$/100 kg (Barton-Gade & Christensen, 1998; Warriss, 1998); however, space allowance did not affect CK concentrations in weaned pigs in this study. Increased concentrations of CK, AST, and BUN in weaned pigs suggest that transport stress may cause a catabolic state due to the exertion of transport; however, this state is not further affected by the three space allowances tested in this study.

Space allowance influenced the behavior of weaned pigs during transport. In this study, pigs transported at 0.06 m$^2$/pig spent more time lying and less time standing than did pigs transported at 0.05 or 0.07 m$^2$/pig. Kim et al. (2004) found that standing behavior during transport was lower in low compared with medium and high stocking density rates in market-weight pigs. In contrast, Barton-Gade and Christensen (1998) found that market-weight pigs transported at lower stocking densities experienced continuous disturbances from other pigs and had more difficulty maintaining balance. In this study, 5.3 kg pigs transported at 0.06 m$^2$/pig displayed less standing-rearing behavior than pigs transported at 0.05 or 0.07 m$^2$/pig. Increased standing-rearing behavior may be an indication of competition for space or instability due to too much space. Increased “resting” and reduced standing-rearing behavior performed by weaned
pigs during transport at a space allowance of 0.06 m²/pigs suggested that this space allowance maybe preferable to 0.05 or 0.07 m²/pig when transporting weaned pigs.

CONCLUSION

The increased blood chemistry values and reduced body weight in transported weaned pigs suggested that these pigs experienced dehydration and muscle breakdown due to transport; however, space allowance did not further affect these values. Different space allowances during transport did not influence any immune or physiological measures in this study; however, differences in behavior were observed among pigs transported at different space allowances.

Therefore, behavior may be a better indicator of stress when assessing the effect of space allowance on the welfare of weaned pigs during transport. Combining behavioral and physiological measures of stress provides a robust picture of pig welfare during transport at different space allowances.

ACKNOWLEDGMENTS

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