

JOURNAL OF ANIMAL SCIENCE

The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science

Space requirements of weaned pigs during a sixty-minute transport in summer

M. A. Sutherland, P. J. Bryer, B. L. Davis and J. J. McGlone

J Anim Sci 2009.87:363-370.

doi: 10.2527/jas.2008-1078 originally published online Sep 2, 2008;

The online version of this article, along with updated information and services, is located on the World Wide Web at:

<http://jas.fass.org/cgi/content/full/87/1/363>



American Society of Animal Science

www.asas.org

Space requirements of weaned pigs during a sixty-minute transport in summer¹

M. A. Sutherland,² P. J. Bryer, B. L. Davis, and J. J. McGlone

Pork Industry Institute, Department of Animal and Food Sciences, Texas Tech University, Lubbock 79409

ABSTRACT: Currently, there are no trucking quality assurance recommendations for space allowance of weaned pigs during transport in the United States. The objective of this research was to establish a first estimate of the space requirements of weaned pigs during transport in summer based on measures of animal well-being. A commercial semi-trailer was fitted with compartments that provided 0.05, 0.06, and 0.07 m²/pig, which were replicated on the upper and lower deck, with a constant 100 pigs per compartment. Cameras were placed in each experimental compartment to record behaviors and postures of pigs during transport. The frequencies of standing, lying, sitting, standing/rearing on another pig, and lying/huddling on top of another pig were recorded using 1-min scan samples during the entire duration of transport. Blood samples were collected and BW and lesion scores recorded from 32 pigs per space allowance for physiological and immune measures before and after transport (n = 32 pigs/treatment). Pigs were transported for 60 ± 5 min to the wean-to-finishing site using the same route for each replicate during summer (temperature: 28.4 ± 1.2°C

and relative humidity: 59.8 ± 4.4% within the trailer). Data were analyzed using the MIXED procedure (SAS Institute Inc., Cary, NC). Cortisol, hematocrit, blood urea nitrogen, total protein, albumin, aspartate aminotransferase, creatine kinase, and gamma-glutamyl transferase increased ($P < 0.05$) after transport regardless of space allowance. Plasma glucose and BW decreased ($P < 0.05$) after transport regardless of space allowance. Lesion scores increased ($P < 0.001$) after transport and were greater ($P < 0.05$) for barrows compared with gilts. The neutrophil to lymphocyte ratio was greater ($P < 0.005$) for pigs transported at 0.05 m²/pig compared with pigs transported at 0.06 and 0.07 m²/pig. Pigs transported at 0.05 m²/pig lay down less ($P < 0.05$) than pigs transported at 0.06 and 0.07 m²/pig between 30 and 60 min of transport. Greater neutrophil to lymphocyte ratio and less lying behavior performed by pigs transported at 0.05 m²/pig suggest that a minimum space allowance of 0.06 m²/pig was preferable when transporting weaned pigs for 60 min during summer in this study.

Key words: animal welfare, cortisol, pig, space requirement, transport

©2009 American Society of Animal Science. All rights reserved.

J. Anim. Sci. 2009. 87:363–370
doi:10.2527/jas.2008-1078

INTRODUCTION

Transport of pigs at weaning is a common practice in the United States. The behavioral and physiological response of weaned pigs to transport is not well documented, and little is known about the optimal space requirement of weanling pigs during transport. Transport is a complex stressor involving temperature fluctuations, stocking density, withdrawal from food and water, and mixing with conspecifics (Lambooij and van Putten, 1993). Stocking density is one important as-

pect of transport that could affect animal health and welfare, especially in pigs already experiencing weaning stress, which has been shown to affect the immune response, performance, and behavior in pigs (Hay et al., 2001; Kanitz et al., 2002).

Most studies evaluating effects of space requirements of pigs during transport have been conducted on market-weight pigs. Greater stocking densities have been associated with greater mortality rates (Warriss, 1998; Ritter et al., 2004). Stocking density during transport has also been shown to influence physiological measures of stress and fatigue in pigs including concentrations of lactate dehydrogenase and creatine phosphokinase (Barton-Gade and Christensen, 1998; Warriss et al., 1998; Kim et al., 2004). The behavior of an animal during transit is also an important factor to take into consideration when determining the appropriate space requirements during transport. Adequate space allow-

¹This project was funded by the National Pork Checkoff. The authors thank J. F. Smith, M. Massey, and T. Bibb for their assistance.

²Corresponding author: mhairi.sutherland@ttu.edu

Received April 1, 2008.

Accepted August 19, 2008.

ance during transit is important because pigs generally prefer to lie down after a period of standing if the conditions are suitable.

Transport stress has been shown to influence several physiological and behavioral measures in pigs. Furthermore, suboptimal space allowance during transport can reduce the welfare and health of pigs. The objective of this research was to establish a first estimate of the space requirements of weaned pigs during a 60-min transport in summer by using a multidisciplinary approach including physiology, immunology, and behavior.

MATERIALS AND METHODS

All animal procedures were approved by the Texas Tech University Animal Care and Use Committee.

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 NRC (1998) nutrient requirements. Pigs were not offered creep feed before weaning. Water was provided ad libitum in the farrowing crates.

A commercial semi-trailer was fitted with experimental compartments that provided 0.05, 0.06, and 0.07 m²/pig. All 3 experimental compartment sizes were represented on the upper and lower decks of the trailer. One hundred pigs were transported in each experimental compartment, so group size did not confound compartment size. This study was replicated 4 times. Only a subset of the 100 pigs were sampled for blood analysis. Over the entire study, 96 BW-matched (5.1 ± 0.10 kg) pigs (18 ± 1 d of age) from 16 sows/litters were allocated to 1 of 3 space allowances: 0.05, 0.06, and 0.07 m²/pig. Barrows and gilt were represented equally over all space allowances. In total, 32 pigs (16 gilts and 16 barrows) per treatment and compartment size were used ($n = 96$ total).

The initial component of this experiment was conducted at a gestation to weaning facility. Before weaning, blood samples were collected from all experimental pigs and pigs were ear tagged, weighed, lesion scored, and then returned to their home pen until weaning. Skin lesions were scored as 0 (no lesions), 1 (minor), or 2 (severe). Blood samples were collected by placing pigs in a supine position and collecting 5 mL of blood from the anterior vena cava using heparin-coated Vacutainers (87 USP units of heparin; BD, Franklin Lakes, NJ; procedure lasted approximately 1 min) for analysis of hematological, blood chemistry, and immune measures. Blood samples were placed on ice after collection until analysis was performed.

Approximately 30 min after blood collection, all pigs (experimental and nonexperimental pigs) were removed from the farrowing crates and moved into holding pens. Experimental pigs were placed with "filler" pigs, so that group size was held constant at 100 pigs per experimen-

tal compartment. Pigs were loaded onto the semi-trailer. Male and female pigs were segregated on different decks of the trailer, as is common practice on commercial swine facilities. The sex of pigs on each deck was alternated so as not to confound trailer deck level with sex 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 which took 60 ± 5 min. The trailer was equipped with Hobo data loggers (Onset Computer Corporation, Bourne, MA) to record temperature, humidity, and wind speed. A Hobo data logger was secured at pig height in each experimental pen within the trailer. Wind speed averaged 1.77 m/s during the entire trip. Temperature ranged from 26.1 to 30.3°C during transport with an average temperature of 28.4 ± 1.23 °C. Relative humidity ranged from 50.0 to 60.0% during transport with an average relative humidity of 59.8 ± 4.42 %.

At the wean-to-finish site, experimental pigs were located, weighed and lesion scored, and a blood sample was collected. Pigs were again held in a supine position and 10 mL of blood was collected from the anterior vena cava using heparin-coated Vacutainers (143 USP units of heparin; BD; procedure lasted 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 and red blood cell counts, differential leukocyte counts, hemoglobin, hematocrit, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentrations, and red blood cell distribution width using a cell counter (Cell-Dyn 1800, Abbott Laboratories, Abbott Park, IL), and the neutrophil to lymphocyte (**N:L**) ratio was calculated by dividing the percentage of granulocytes by the percentage of lymphocytes. Blood samples were centrifuged for 20 min at $660 \times g$ at room temperature and plasma collected for analysis of cortisol concentrations and blood chemistry measures. Cortisol and blood chemistry were analyzed on only half of the samples ($n = 16$ pigs/treatment). Cortisol concentrations were analyzed using an enzyme immunoassay kit with a sensitivity of 0.6 ng/mL (Assay Designs, Ann Arbor, MI). Intra- and interassay CV were 6.3 and 6.7%, respectively. The use of this assay was published in Sutherland et al. (2008). Blood chemistry was analyzed using the Roche/Hitachi 912 auto-analyzer (Roche Diagnostics, Basel, Switzerland) for blood urea nitrogen (**BUN**), creatinine, glucose, total protein, albumin, aspartate aminotransferase (**AST**), creatine kinase (**CK**), alkaline phosphatase, gamma-glutamyl transferase, 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 number of latex beads engulfed by neutrophils, and

Table 1. Description of behaviors

Behavior	Description
Sitting ¹	Resting on the caudal part of the body
Standing ¹	Assuming or maintaining an upright position on extended legs
Standing/rearing on another pig	Assuming or maintaining an upright position on extended legs while standing on another pig(s)
Lying ¹	Maintaining a recumbent position and not in contact with other pigs
Lying/huddling on top of another pig	Maintaining a recumbent position while contacting another pig(s)

¹Hurnik et al. (1995).

the percentage of cells phagocytosing at least one bead was calculated as described previously (Hulbert and McGlone, 2006). The chemotaxis assay was performed according to published methods (Salak et al., 1993; Hulbert and McGlone, 2006). Briefly, migration of neutrophils across a polyvinylpyrrolidone-free filter (pore size of 5 μm ; Neuro Probe, Molecular Probes, Eugene, OR) toward media or recombinant human complement C5a (chemotaxis) was measured.

Behavior

Digital still cameras were placed in each experimental compartment to record the behavior and postures of the pigs during transport (Table 1). Cameras were programmed to take 1 picture per minute (1-min scan samples). Behaviors and postures measured included lying, standing, sitting, standing/rearing on top of another pig, and lying/huddling 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 transport period and divided into four 15-min periods.

Trailer Design

A Wilson-brand straight deck stock trailer (Wilson Trailer Company, Sioux City, IA) was used during all replications of this study. The trailer was fitted with an upper and a 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 3 space allowances were represented on each of the upper and lower decks of the trailer. Wood shavings were spread over the upper and lower decks before the pigs were 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 ANOVA using the MIXED procedure (SAS Inst. Inc., Cary, NC). Data were analyzed as a random complete block with the trailer as the block. The experimental unit was the pen. The main fixed effects were block (4 levels), sex (2 levels), deck (2

levels), treatment (3 levels), and time (2 levels). Random effects in the model were litter (16 levels) and piglet (96 levels). The interaction between treatment and time ($df = 4$) and treatment and deck ($df = 4$) were included in the model. A total of 16 litters and 96 pigs (treatment, $n = 32$; gilts, $n = 16$ and barrows, $n = 16$) were used in this study. Gilts and barrows were balanced within each sampling period. Behavioral data were also analyzed using ANOVA using the MIXED procedure (SAS Institute Inc.). The behavior observation period was divided into four 15-min periods. For behavioral measures, the main fixed effects were block (4 levels), sex (2 levels), deck (2 levels), treatment (3 levels), and period (4 levels). The interaction between treatment and period ($df = 5$) and treatment and deck ($df = 4$) were included in the model.

RESULTS

Total white blood cell counts and the percentage of neutrophils were greater ($P < 0.001$) after transport in pigs regardless of space allowance, and conversely, the percentage of lymphocytes was decreased ($P < 0.001$) in pigs after transport regardless of space allowance (Table 2). No sex, deck, or treatment \times deck effects were observed for white blood cell measures ($P > 0.05$).

The N:L ratio was greater ($P < 0.001$) for pigs after transport compared with the baseline ratio regardless of space allowance (Figure 1). The N:L ratio was greater ($P < 0.005$) for pigs transported at 0.05 m^2/pig compared with pigs transported at 0.06 and 0.07 m^2/pig (Figure 1).

Hematocrit was increased ($P < 0.006$) and mean corpuscular volume was decreased ($P < 0.005$) for pigs after transport regardless of space allowance (Table 2). No other differences ($P > 0.05$) in hematological values were observed. No sex, deck, or treatment \times deck effects were observed for hematological values ($P > 0.05$).

Plasma cortisol concentrations were greater ($P < 0.001$) than baseline after transport regardless of space allowance (Table 3). No sex, deck, or treatment \times deck effects were observed for cortisol concentrations ($P > 0.05$).

Blood glucose concentrations were decreased ($P < 0.001$) in pigs after transport regardless of space allowance (Table 3). Blood urea nitrogen, albumin, AST, CK, and gamma-glutamyl transferase were greater (P

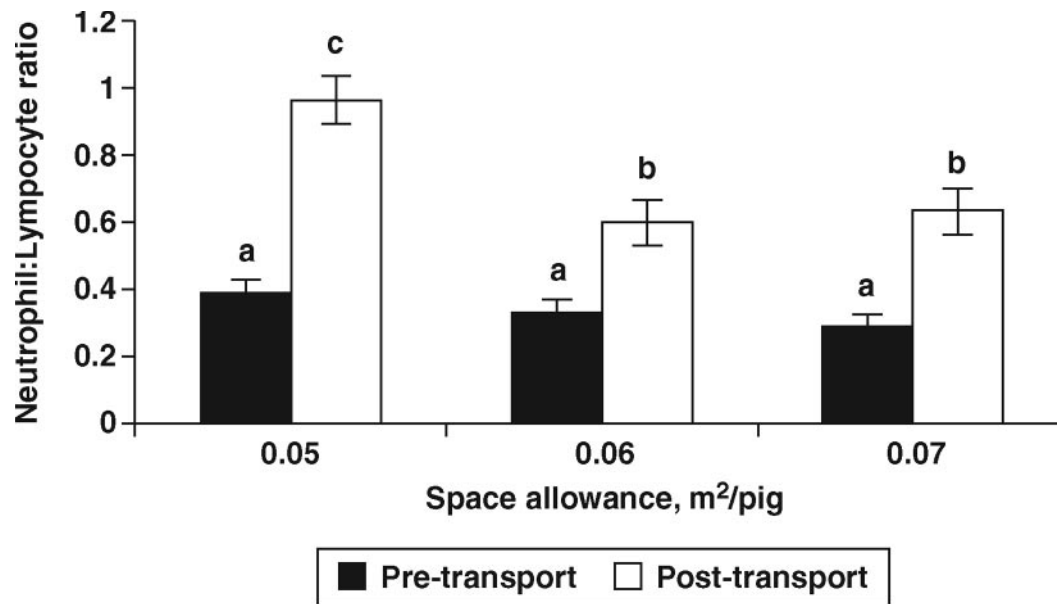


Figure 1. The neutrophil to lymphocyte ratio of pigs shipped at 0.05 m²/pig (n = 32), 0.06 m²/pig (n = 32), and 0.07 m²/ pig (n = 32) pre- and post-transport in summer. Least squares means ± SE accompanied by different letters are different at $P < 0.05$.

< 0.01) for pigs after transport regardless of space allowance (Table 3). No sex, deck, or treatment × deck effects were observed for blood chemistry values ($P > 0.05$).

Chemotaxis in response to the mitogen human complement C5a did not differ ($P > 0.05$) among pigs transported at different space allowances (0.05 m²/pig: 9.2 ± 2.05 cells/5 fields; 0.06 m²/pig: 6.2 ± 2.20 cells/5 fields; 0.07 m²/pig: 5.0 ± 2.13 cells/5 fields). For all results, the least squares means and SE are presented. The percentage of neutrophils that engulfed at least one latex bead did not differ ($P > 0.05$) among pigs transported at different space allowances (0.05 m²/pig: 91.7 ± 2.54%; 0.06 m²/pig: 89.8 ± 2.76%; 0.07 m²/pig:

95.9 ± 2.65%). No sex, deck, or treatment × deck effects were observed for immune measures ($P > 0.05$).

Body weight decreased ($P < 0.05$) after transport, regardless of space allowance (before transport: 5.2 ± 0.08 kg; after transport: 5.0 ± 0.07 kg). Skin lesion scores increased ($P < 0.001$) after transport, regardless of space allowance (before transport: 0.08 ± 0.030; after transport: 0.67 ± 0.072). Furthermore, lesion scores were greater ($P < 0.05$) in barrows than gilts (barrows: 0.4 ± 0.05; gilts: 0.3 ± 0.05).

Pigs transported at 0.05 m²/pig spent less ($P < 0.05$) time lying than pigs transported at 0.06 or 0.07 m²/pig between 16 and 60 min after transport (Figure 2). Pigs transported at 0.05 m²/pig spent more ($P < 0.05$) time

Table 2. Blood hematological values of weaned pigs before and after a 60-min transport period in summer

Item	Before transport		After transport		P-value
	Mean	SE	Mean	SE	
Animals, No.	96		96		
Total white blood cell count, 10 ³ /μL	11.3	0.43	14.3	0.55	0.001
Neutrophil cell count, 10 ³ /μL	2.3	0.13	4.2	0.21	0.001
Lymphocyte cell count, 10 ³ /μL	6.7	0.23	5.9	0.20	0.007
Neutrophils, %	18.3	0.65	28.2	0.97	0.001
Lymphocytes, %	61.0	0.80	43.4	1.04	0.001
Neutrophil to lymphocyte ratio	0.34	0.020	0.74	0.042	0.001
Red blood cell count, 10 ⁶ /μL	5.5	0.08	5.8	0.08	0.064
Hemoglobin, g/dL	113.4	2.00	117.9	2.12	0.127
Hematocrit, %	31	0.5	33	0.6	0.006
Mean corpuscular volume, fL	56.9	0.43	57.2	0.45	0.661
Mean corpuscular hemoglobin, g/dL	19.5	0.19	19.2	0.20	0.425
Mean corpuscular hemoglobin concentration, pg	343.8	1.50	337.2	1.51	0.005
Red cell distribution width, %	25.1	0.34	25.4	0.35	0.530

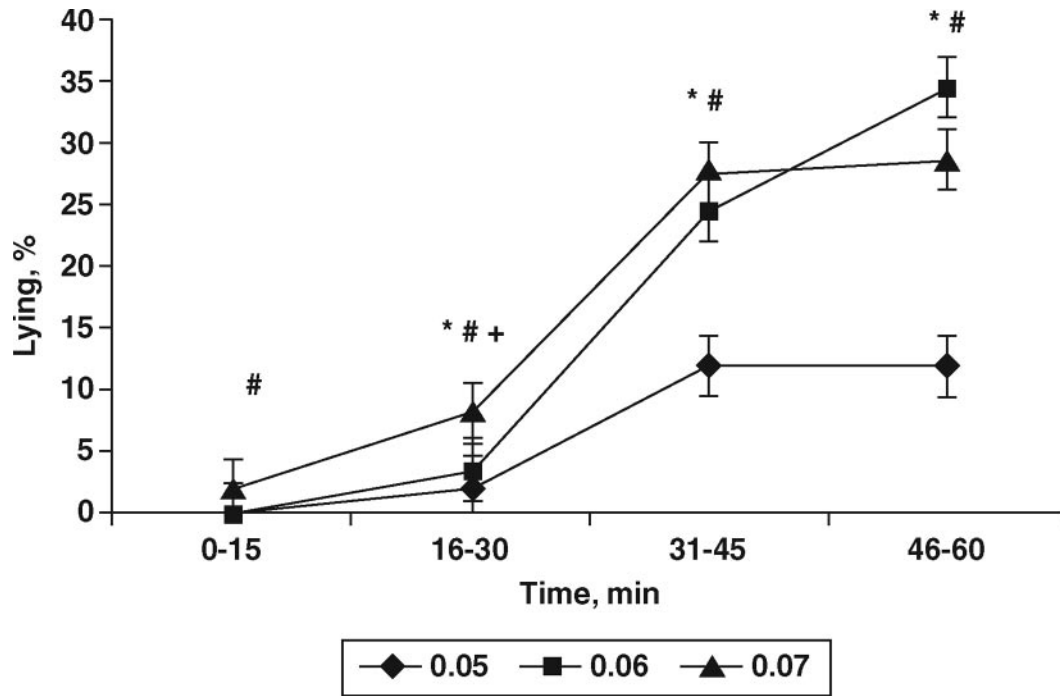


Figure 2. The percentage of time pigs spent lying when shipped at 0.05 m²/pig (◆), 0.06 m²/pig (■), and 0.07 m²/pig (▲) during a 60 min transport period in summer. In each time period, least squares means ± SE accompanied by a * indicates that 0.05 m²/pig differed ($P < 0.05$) from 0.06 m²/pig; # indicates that 0.05 m²/pig differed ($P < 0.05$) from 0.07 m²/pig; and + indicates that 0.06 m²/pig differed ($P < 0.05$) from 0.07 m²/pig.

standing than pigs transported at 0.06 and 0.07 m²/pig during the last 15 min of transport (Figure 3).

Pigs spent less ($P < 0.001$) time sitting during transport at 0.07 m²/pig compared with pigs transported at 0.05 and 0.06 m²/pig (0.05 m²/pig: 12.7 ± 0.67%; 0.06 m²/pig: 12.2 ± 0.61%; 0.07 m²/pig: 7.4 ± 0.61%). Pigs spent more ($P < 0.001$) time standing/rearing during transport at 0.05 m²/pig compared with pigs transported at 0.06 and 0.07 m²/pig (0.05 m²/pig: 6.7 ± 0.30%; 0.06 m²/pig: 2.8 ± 0.27%; 0.07 m²/pig: 2.3 ± 0.27%). Pigs spent more ($P < 0.001$) time lying/huddling during transport at 0.07 m²/pig compared with pigs transported at 0.05 and 0.06 m²/pig (0.05 m²/pig:

1.8 ± 0.29%; 0.06 m²/pig: 2.2 ± 0.27%; 0.07 m²/pig: 3.0 ± 0.27%).

DISCUSSION

A 60-min transport during summer resulted in elevated blood chemistry values and cortisol concentrations in weaned pigs. Increased cortisol concentrations and N:L ratio suggest that these pigs experienced stress regardless of space allowance. The N:L ratio and cortisol concentrations were also increased in young pigs after a 4-h transport (McGlone et al., 1993). The N:L ratio was greater for pigs transported at 0.05 m²/pig

Table 3. Blood chemistry and cortisol concentrations of weaned pigs before and after a 60-min transport period in summer

Item	Before transport		After transport		<i>P</i> -value
	Mean	SE	Mean	SE	
Animals, No.	48		48		
Cortisol, ng/mL	92.7	17.68	144.6	17.37	0.001
Glucose, mmol/L	6.9	0.13	5.8	0.13	0.001
Blood urea nitrogen, mmol/L	2.4	0.09	2.9	0.09	0.005
Creatinine, μmol/L	81.0	3.37	73.2	2.80	0.111
Total bilirubin, μmol/L	6.1	0.42	6.4	0.49	0.900
Total protein, g/L	49.9	0.62	51.5	0.60	0.053
Albumin, g/L	32.4	0.45	34.5	0.45	0.001
Aspartate aminotransferase, U/L	53.6	3.66	64.0	2.41	0.001
Creatine kinase, U/L	903	121.4	1,100	97.6	0.01
Alkaline phosphatase, U/L	666	22.0	659	22.3	0.876
Gamma-glutamyl transferase, U/L	56.7	3.04	97.4	7.66	0.001

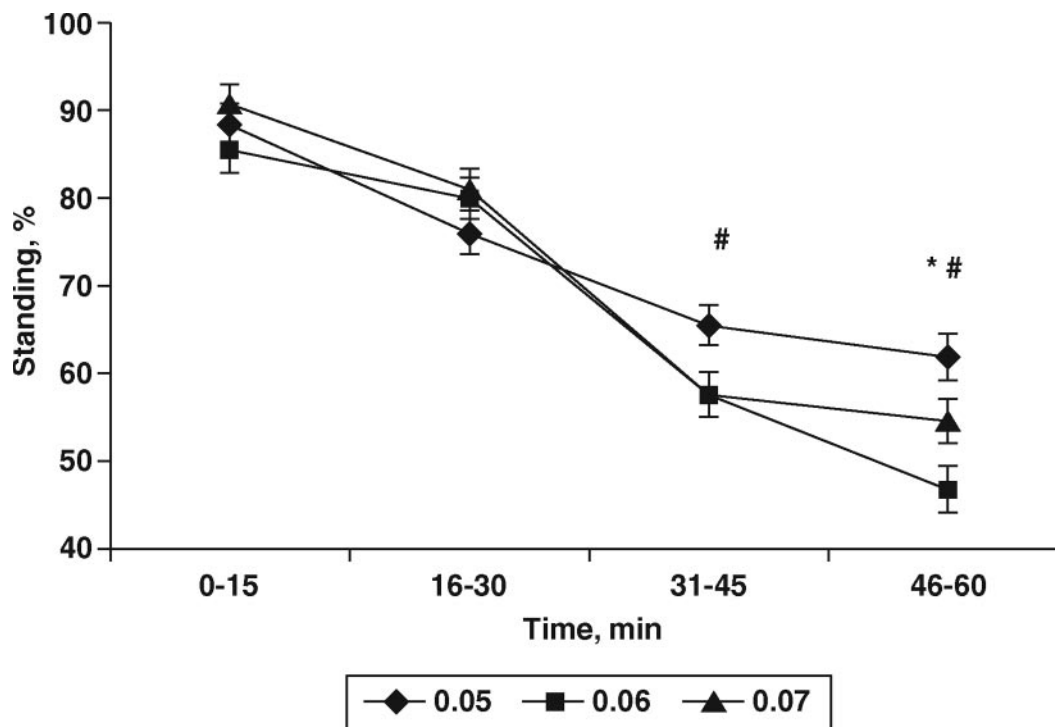


Figure 3. The percentage of time pigs were observed standing when shipped at 0.05 m²/pig (◆), 0.06 m²/pig (■), and 0.07 m²/pig (▲) during a 60 min transport period in summer. In each time period, least squares means ± SE accompanied by a * indicates that 0.05 m²/pig differed ($P < 0.05$) from 0.06 m²/pig; # indicates that 0.05 m²/pig differed ($P < 0.05$) from 0.07 m²/pig.

compared with pigs transported at 0.06 or 0.07 m²/pig, suggesting that pigs transported at 0.05 m²/pig may have experienced more stress than pigs transported at 0.06 or 0.07 m²/pig. Transport caused a stress response in weaned pigs that may have been exacerbated for pigs transported at 0.05 m²/pig.

Space allowance influenced the behavior of weaned pigs during transport. Pigs transported at 0.05 m²/pig lay down less than pigs transported at 0.06 and 0.07 m²/pig between 30 and 60 min after transport, suggesting that pigs transported at 0.05 m²/pig were more restless than pigs transported at 0.06 or 0.07 m²/pig. Early-weaned pigs transported between 0 and 6 h at a space allowance of 0.06 m²/pig rested for 71% and stood for 26.5% of the time during transport in summer (Lewis and Berry, 2006). In the present study, weaned pigs transported for 60 min at a space allowance of 0.06 m²/pig spent 68% of the time standing and 19% of the time lying. The differences between these studies are probably due to differences in the length of transport. At the beginning of the transport period in the present study 88% of pigs were standing, whereas during the last 15 min of the trip only 49% of the pigs were standing, suggesting that given a longer transport duration pigs in this study would have spent more time lying down. Kim et al. (2004) found that standing behavior during transport was less in low (0.39 m²/100 kg) compared with medium (0.35 m²/100 kg) and high (0.31 m²/100 kg) stocking density rates in market-weight pigs. However, Barton-Gade and Christensen (1998) did not find that giving market-weight pigs more space

resulted in more lying behavior; on the contrary, they observed continuous disturbances from other pigs, and, at stocking densities of 0.42 m²/100 kg and 0.5 m²/100 kg, pigs had more difficulty maintaining balance. In the present study, the behavior of weaning pigs during transport suggests that a space allowance of 0.06 or 0.07 m²/pig was preferable to 0.05 m²/pig when transporting weaned pigs.

Creatine kinase is released from muscle fibers into the circulation in response to exercise or tissue damage and is a good indicator of muscular activity or tissue damage (Van der Meulen et al., 1991; Fàbrega et al., 2002; Yu et al., 2007). Creatine kinase was greater in weaned pigs after transport, regardless of space allowance. Values of CK measured after transport were in the upper limit of the normal range for CK (Carr, 1998). Creatine kinase concentrations also increased in slaughter-weight pigs in response to transport stress (Elbers et al., 1991; Fàbrega et al., 2002). Furthermore, CK concentrations increased in market-weight pigs kept at stocking densities less than 0.5 m²/100 kg during transport (Barton-Gade and Christensen, 1998; Warriss, 1998); however, space allowance did not affect CK concentrations in weaned pigs in this study.

Aspartate aminotransferase, which is widely distributed in the myocardium, liver, and skeletal muscles, is a good indicator of muscular activity or tissue damage (Van der Meulen et al., 1991; Yu et al., 2007). Aspartate aminotransferase was increased in transported pigs regardless of space allowance, but was within the normal range for weaned pigs (Carr, 1998). Elevated

CK and AST concentrations measured in transported weaned pigs were probably due to tissue damage caused by muscle exertion as a result of transport, but concentrations were still within the normal range for these enzymes, suggesting that the welfare of these pigs was not compromised.

Blood urea nitrogen is a metabolic waste product in the blood generated from the breakdown of protein. Concentrations of BUN in this study were in the upper limit or slightly above the normal range (Carr, 1998; Mersmann and Pond, 2001) in weaned pigs after transport. The increased BUN concentrations among transported pigs may indicate muscle and protein breakdown. Therefore, increased concentrations of BUN in addition to increased CK and AST in pigs after transport suggest that pigs may have been in a catabolic state because of exertion during transport.

Total plasma protein and plasma albumin concentrations are markers for protein homeostasis, which increase with dehydration. Albumin concentrations usually parallel total protein concentrations. Total protein and albumin were increased but within the normal range (Carr, 1998; Mersmann and Pond, 2001) for weanling-age pigs, suggesting that pigs may have been experiencing mild dehydration as a result of transport. In addition, hematocrit increased and BW was less after transport compared with baseline, further suggesting that these pigs were mildly dehydrated as a result of a 60-min transport.

Skin lesion scores were greater in barrows than in gilts overall. One possibility is that barrows may fight more than gilts. However, McGlone (1985) found that the frequency of aggressive behavior after mixing young pigs did not differ between young gilts and castrated males. Weaning and transporting pigs involve the mixing of unfamiliar pigs, which often results in fighting to establish new dominance orders (McGlone, 1985). Fighting in pigs can cause stress, possibly resulting in fatigue (Warriss, 1998). Lewis and Berry (2006) found that early-weaned pigs transported at 0.06 m²/pig showed infrequent fighting during transport, but more pigs were shown to fight when transported in summer compared with winter. Therefore, fighting of pigs during weaning and transport could add to the stress response experienced by pigs during transport and, furthermore, cause an increase in indices of muscle damage such as CK and AST concentrations.

The increased blood chemistry values and reduced BW in transported weaned pigs suggest that these pigs were experiencing 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, the greater N:L ratio and increased standing behavior in pigs transported at 0.05 m²/pig suggest that space allowances of 0.06 and 0.07 m²/pig are preferable when transporting pigs for 60 min in summer. This study was designed

to determine a first estimate of space requirements of weaned pigs during transport. Further research is necessary before trucking quality assurance recommendations can be made regarding the space requirements of weaned pigs during transport in summer.

LITERATURE CITED

- Barton-Gade, P., and L. Christensen. 1998. Effect of different stocking densities during transport on welfare and meat quality in Danish slaughter pigs. *Meat Sci.* 48:237-247.
- Carr, J. 1998. Garth pig stockmanship standards. 5M Enterprises Limited, Sheffield, UK.
- Elbers, A. R. W., I. J. R. Visser, J. Odink, and J. F. Smeets. 1991. Changes in haematological and clinicochemical profiles in blood of apparently healthy slaughter pigs, collected at the farm and at slaughter, in relation to the severity of pathological-anatomical lesions. *Vet. Q.* 13:1-9.
- Fàbrega, E., X. Manteca, J. Font, M. Gispert, D. Carrión, A. Velarde, J. L. Ruiz-de-la-Torre, and A. Diestre. 2002. Effects of halothane gene and pre-slaughter treatment on meat quality and welfare from two pig crosses. *Meat Sci.* 62:463-472.
- Hay, M., P. Orgeur, F. Levy, J. Le Dividich, D. Concordet, R. Nowak, B. Schaal, and P. Mormede. 2001. Neuroendocrine consequences of very early weaning in swine. *Physiol. Behav.* 72:263-269.
- Hulbert, L. E., and J. J. McGlone. 2006. Evaluation of drop versus trickle feeding systems for crated or group-penned gestating sows. *J. Anim. Sci.* 84:1004-1014.
- Hurnik, J. F., A. B. Webster, and P. B. Siegel. 1995. *Dictionary of Farm Animal Behavior*. Iowa State University Press, Ames.
- Kanitz, E., M. Tuchscherer, A. Tuchscherer, B. Stabenow, and G. Manteuffel. 2002. Neuroendocrine and immune response to acute endotoxemia in suckling piglets. *Biol. Neonate* 81:203-209.
- Kim, D. H., J. H. Woo, and C. Y. Lee. 2004. Effects of stocking density and transportation time of market pigs on their behaviour, plasma concentrations of glucose and stress-associated enzymes and carcass quality. *Asian-australas. J. Anim. Sci.* 17:116-121.
- Lambooi, E., and G. van Putten. 1993. *Transport of pigs*. Pages 213-231 in *Livestock Handling and Transport*. T. Grandin, ed. CAB International, Wallingford, UK.
- Lewis, N. J., and R. L. Berry. 2006. Effects of season on the behavior of early-weaned piglets during and immediately following transport. *Appl. Anim. Behav. Sci.* 100:182-192.
- McGlone, J. J. 1985. A quantitative ethogram of aggressive and submissive behaviors in recently regrouped pigs. *J. Anim. Sci.* 61:559-565.
- McGlone, J. J., J. L. Salak-Johnson, E. A. Lumpkin, R. I. Nicholson, M. Gibson, and R. L. Norman. 1993. Shipping stress and social status effects on pig performance, plasma cortisol, natural killer cell activity, and leukocyte numbers. *J. Anim. Sci.* 71:888-896.
- Mersmann, H. J., and W. G. Pond. 2001. *Hematology and Blood Serum Constituents in Biology of the Pig*. Cornell University Press, Ithaca, NY.
- NRC. 1998. *Nutrition Requirements of Swine*. National Academy Press, Washington, DC.
- Ritter, M. J., M. Ellis, J. Brinkmann, J. M. DeDecker, M. E. Kocher, K. Keffaber, B. A. Peterson, J. M. Schlipf, and B. F. Wolter. 2004. The effects of stocking density during transport of slaughter weight pigs on the incidence of dead and non-ambulatory pigs at the packing plant. Page 8 in *Proc. 57th Annu. Recip. Meat Conf.*, Lexington, KY.
- Salak, J. L., J. J. McGlone, and M. Lyte. 1993. Effects of in vitro adrenocorticotrophic hormone, cortisol and human recombinant interleukin-2 on porcine neutrophil migration and luminal-

- dependent chemiluminescence. *Vet. Immunol. Immunopathol.* 39:327–337.
- Sutherland, M. A., P. J. Bryer, N. Krebs, and J. J. McGlone. 2008. Tail docking in pigs: Acute physiological and behavioral responses. *Animal* 2:292–297.
- Van der Meulen, J. H., H. Kuipers, and J. Drukker. 1991. Relationship between exercise-induced muscle damage and enzyme release in rats. *J. Appl. Physiol.* 71:999–1004.
- Warriss, P. D. 1998. Choosing appropriate space allowances for slaughter pigs transported by road: A review. *Vet. Rec.* 142:449–454.
- Warriss, P. D., S. N. Brown, T. G. Knowles, J. E. Edwards, P. J. Kettlewell, and H. J. Guise. 1998. The effect of stocking density in transit on the carcass quality and welfare of slaughter pigs: Results from the analysis of blood and meat samples. *Meat Sci.* 50:447–456.
- Yu, H., E. D. Bao, R. Q. Zhao, and Q. X. Lv. 2007. Effect of transportation stress on heat shock protein 70 concentration and mRNA expression in heart and kidney tissues and serum enzyme activities and hormone concentrations of pigs. *Am. J. Vet. Res.* 68:1145–1150.

References

This article cites 16 articles, 4 of which you can access for free at:
<http://jas.fass.org/cgi/content/full/87/1/363#BIBL>