Effects of variations in the environment, length of journey and type of trailer on the mortality and morbidity of pigs being transported to slaughter

M. A. Sutherland, A. McDonald, J. J. McGlone

The month, average air temperature, relative humidity, number of pigs of each sex per trailer load, journey time, type of trailer and bedding, and waiting time at the processing plant were recorded from 16,323 trailers transporting 2,730,754 pigs to a packing plant in the USA during a year, together with the numbers of pigs that were dead on arrival, injured or unable to walk. The percentage of pigs dead on arrival increased at temperatures above 20°C, and the percentage of pigs unable to walk increased at temperatures of 5°C or below. The journey time and waiting time at the processing plant influenced the percentages of dead and injured pigs and pigs unable to walk.

MOST commercial pigs are transported by truck from the farm to the processing plant, and most of them arrive and are processed without incident. However, a small percentage of pigs are dead on arrival and some pigs have difficulty in walking during unloading and are commonly referred to as 'downers', 'fatigued', 'subjects', 'suspects', 'slows' or 'non-ambulatory, non-injured' ('NANI') pigs (Ellis and others 2003). Although the percentage of losses is low, it is of economic concern for producers and also a significant welfare concern.

The potential factors that might affect the percentage of dead and NANI pigs include genetics (Ellis and others 2003), the handling of the pigs before and after the journey (Peeters and others 2004), stress caused by being mixed with other pigs and being exposed to a novel environment, air temperature, relative humidity, the number of pigs per trailer load, journey time, and waiting time at the processing plant. In a retrospective examination of field data, Rademacher and Davies (2005) found that the mortality of pigs being transported increased at temperatures above 26°C and on journeys lasting 30 to 90 minutes.

There have been few studies of the incidence or causes of dead and NANI pigs under commercial conditions directly related to the factors involved in their transport. The objective of this study was to record a range of variables that might be involved when transporting pigs under commercial conditions.

Materials and methods

Prospective data were collected from 16,323 trailers transporting 2,730,754 pigs to a processing plant in Midwest USA between May 2004 and April 2005. The pigs came from approximately 1500 different farms or units. Data sheets, completed by trained staff at the packing plant, contained the headings: date, air temperature (outside the trailer), relative humidity (outside the trailer), number of pigs per trailer load, journey time to the processing plant, waiting time at the plant, type of trailer (pot-belly or straight-deck), bedding (wet, dry or none), and the sex of the pigs in each trailer (barrow [young castrated male], gilt [young female] or mixed). The temperature and humidity were recorded when the trailer arrived at the plant. The completed data sheets were sent weekly by fax to the investigators for data entry and analyses. The numbers and percentages of dead and NANI pigs on each trailer were classified into three categories: dead on arrival (DOA), injured on trailer (IOT) and down on trailer or before they were weighed (NANI). Pigs that died, became injured or were classed as NANI after being unloaded from the trailer were not included in the data. The weighing scale was the first stop for the pigs coming off the trailer. Before weighing, NANI pigs were the responsibility of the producer but after weighing they belonged to the plant. The weights of the pigs on the trailers were not recorded, but the weights of pigs sent to market can range from 115 to 135 kg.

Two types of trailers were used to transport the pigs from the farms. There were 8043 pot-belly and 8224 straight-deck trailers (Fig 1). The trailer designs might have differed slightly, but in general the design of a pot-belly trailer consists of the front and back section of the trailer being placed over the two front and two back axles of the trailer and the floor of the middle section descending below the front and back sections. The dimensions of commonly used straight-deck and pot-belly livestock trailers in the USA are approximately 14·7 to 16·2 m long and 2·6 m wide, regardless of the make. Both types of trailer had at least two decks and a variable number of compartments per deck, depending on the type. They did not have any mechanical ventilation. There were 56 trailers that were neither pot-belly nor straight-deck, and these were removed from the analysis of trailer type.

There were 3359 trailers recorded as having no bedding, 9220 with dry bedding and 3711 with wet bedding. The bedding consisted of standard wood shavings, usually pine, and it was recorded as 'wet' when standing water was observed within it. There were 33 trailer loads on which

Veterinary Record (2009) **165,** 13-18

M. A. Sutherland, PhD,
A. McDonald, MS,
J. J. McGlone, PhD,
Department of Animal and Food Sciences, Pork Industry Institute, Texas Tech University, Lubbock, TX 79409, USA

E-mail for correspondence: mhairi.sutherland@ttu.edu

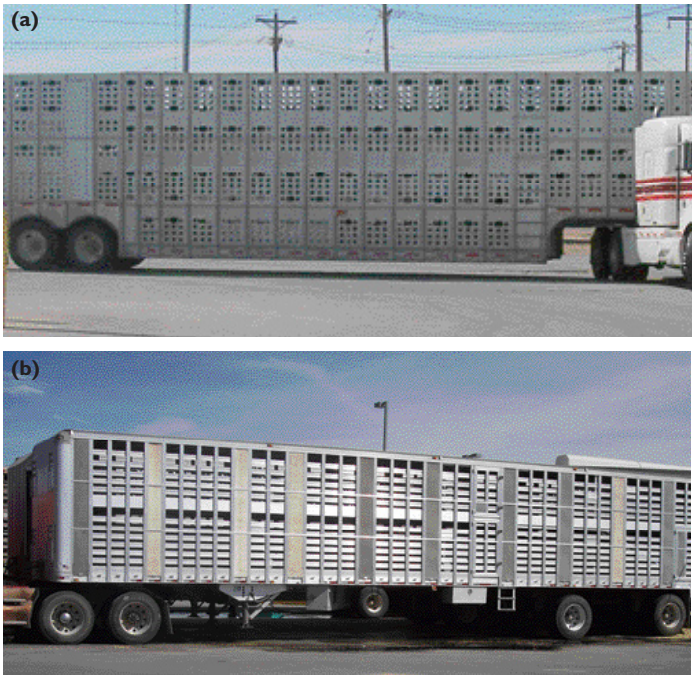

FIG 1: Examples of (a) a pot-belly trailer and (b) a straight-deck trailer used to carry pigs

bedding was not recorded and these were removed from the analyses of bedding.

The sex of the pigs on each trailer was recorded as either barrows (on 1323 trailers), gilts (on 1665 trailers) or mixed groups (on 10,943 trailers). Sex was not recorded in May and June 2004, before the possible importance of sex on the percentages of dead, injured and NANI pigs was realised. The 2392 trailer loads of unknown sex were not included in the analyses of sex.

Statistical analyses

The data were tested for departures from normal distribution by Shapiro-Wilk's test, and non-normal data were transformed logarithmically. The trailer was the experimental unit. The percentages of DOA, IOT and NANI pigs were analysed by a linear mixed-effects model using the MIXED procedure of SAS. The effects of the model included the fixed effects of trailer type (two levels), bedding (three levels) and sex (three levels). The interactions between sex and trailer type and bedding were included in the model. Additional models included the continuous effects of month (12 levels), temperature (eight levels), relative humidity (seven levels), number of pigs per trailer (six levels), journey time to the processing plant (18 levels) and waiting time at the processing plant (eight levels). The interaction fixed effects (sex, trailer type and bedding) and continuous effects (month, temperature, relative humidity, number of pigs per trailer load, journey time and waiting time) were included in the model. Values were considered significant at $P<0.05$.

The continuous variables (temperature, relative humidity, number of pigs per trailer, journey time and waiting time) were grouped into intervals. The ranges for the intervals for the different variables were selected so that there were approximately the same number of data points per interval, or by using logical interval increments.

For the measurements of temperature and journey time, the regression analyses indicated that the best fit was a broken line. The broken-line analyses were performed in Microsoft Excel. Model iterations, scaling over each x variable, were calculated and the lines that maximised r^2 were identified. The break points were also identified by this procedure.

Results

The numbers of trailer loads that reported DOA, IOT and NANI pigs, and the mean, minimum and maximum percentages of DOA, IOT and NANI pigs are shown in Table 1. Of the 16,323 trailer loads, 3358 (20·6 per cent) recorded DOA pigs, 1126 (6·9 per cent) recorded IOT pigs and 3624 (22·2 per cent) recorded NANI pigs. The top 5 per cent of trailer loads of pigs that recorded DOA, IOT or NANI pigs accounted for less than 20 per cent of the total incidences of DOA, IOT and NANI pigs (19·3, 8·4 and 17·5 per cent, respectively).

TABLE 1: Numbers of trailer loads that reported pigs dead on arrival (DOA), injured on trailer (IOT), down on trailer or before weighing (NANI) and total dead or NANI (N&D) at the processing plant, and the mean, minimum and maximum percentages of pigs for each

	DOA	IOT	NANI	N&D
Number of trailer loads	3358	1126	3624	6234
Mean (%)	0·19	0·05	0·22	0·46
Minimum (%)	0	0	0	0
Maximum (%)	50·0	3·23	12·35	50·0

Effects of month

From July to December, the percentage of DOA pigs increased linearly ($r^2=0.90$, $P<0.01$) (Fig 2), and was greater in October ($P<0.005$), November ($P<0.05$) and December ($P<0.05$) than in July. The percentage of DOA decreased ($r^2=0.91$, $P<0.01$) from January to April, the percentage in April being 62·6 per cent lower ($P<0.01$) than in January. The changes in the percentage of NANI pigs showed a similar pattern. From July to December, the percentage of NANI pigs increased linearly ($r^2=0.91$, $P<0.01$) and was greater in August ($P<0.005$), September ($P<0.05$), October ($P<0.001$), November ($P<0.001$), December ($P<0.001$), January ($P<0.07$) and February ($P<0.001$) than in July. The percentage of NANI pigs decreased ($r^2=0.94$, $P<0.05$) from December to June, and was lower in January ($P<0.001$), March ($P<0.005$), April ($P<0.001$), May ($P<0.05$) and June ($P<0.001$) than in December. In contrast, the percentage of IOT pigs increased linearly ($r^2=0.92$, $P<0.01$) from January to April, and was greater in March ($P<0.001$) and April ($P<0.005$) than in January. From July to December, the percentage of IOT pigs tended to decrease ($r^2=0.62$, $P<0.05$), with the percentages in October ($P<0.05$) and December ($P<0.05$) being lower than in June.

Effects of temperature and humidity

Changes in relative humidity had no effect on any of the variables measured, but the percentage of DOA pigs increased ($r^2=0.95$, $P<0.01$) at temperatures above 20°C (Fig 3), the highest ($P<0.05$) percentage being recorded at temperatures of 25°C and above. Conversely, the percentage of NANI pigs decreased ($r^2=0.91$, $P<0.01$) as the temperature increased above 0°C (Fig 3), and was 53·4 per cent lower ($P<0.05$) at temperatures at and above 5°C than at temperatures below 5°C. Temperature had no significant effect on the percentage of IOT pigs (Fig 3).

Effects of number of pigs per trailer, journey time and waiting time

The percentage of NANI pigs was influenced ($P<0.001$) by the number of pigs per trailer (Table 2). It was 64·1 per cent higher ($P<0.05$) in trailers with fewer than 160 pigs than in trailers with larger numbers of pigs. The lowest ($P<0.05$) percentage of NANI pigs occurred in trailers with 170 to 174 and 180 or more pigs. The percentage of total dead or NANI pigs was 79·0 per cent higher ($P<0.05$) in trailers containing 169 or fewer pigs than in trailers with 170 or more pigs.

The journey time to the processing plant influenced ($P<0.001$) the percentage of DOA, IOT, NANI, and total dead or NANI pigs (Fig 4). The percentage of DOA pigs increased ($r^2=0.87$, $P<0.01$) as the journey time increased from 30 minutes to four hours, but tended to decrease ($r^2=0.80$, $P<0.01$) for longer journeys. The percentage of IOT pigs also increased ($r^2=0.73$, $P<0.01$) as the journey time increased, and was greater ($P<0.05$) for journeys longer than three-and-a-half hours than for journeys of less than an hour. Conversely, the percentage of NANI pigs decreased ($r^2=0.93$, $P<0.01$) as the journey time increased and the lowest percentage was recorded for journeys lasting more than 11 hours. Overall, the effect of journey time on the total percentage of dead or NANI pigs was similar to its effect on the percentage of DOA pigs; it increased ($r^2=0.69$, $P<0.01$) for journeys lasting more than 30 minutes

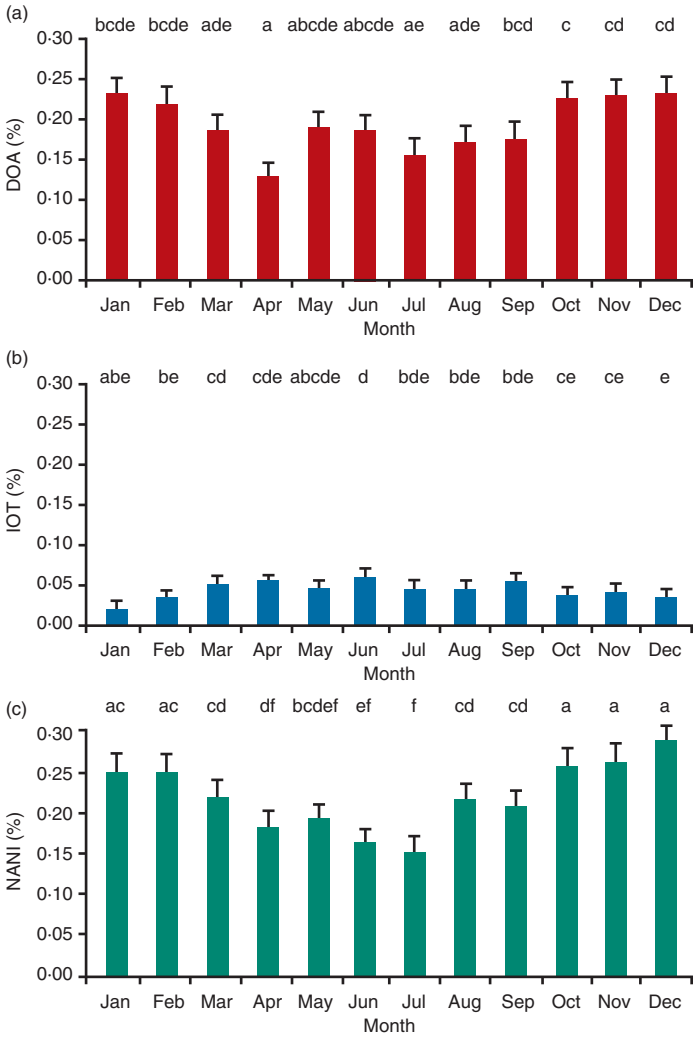

FIG 2: Least square mean (se) percentages of pigs (a) dead on arrival (DOA), (b) injured on trailer (IOT) and (c) down on trailer or before weighing (NANI) in each month during their transport to the processing plant. Mean values with different letters are significantly different at P<0·05

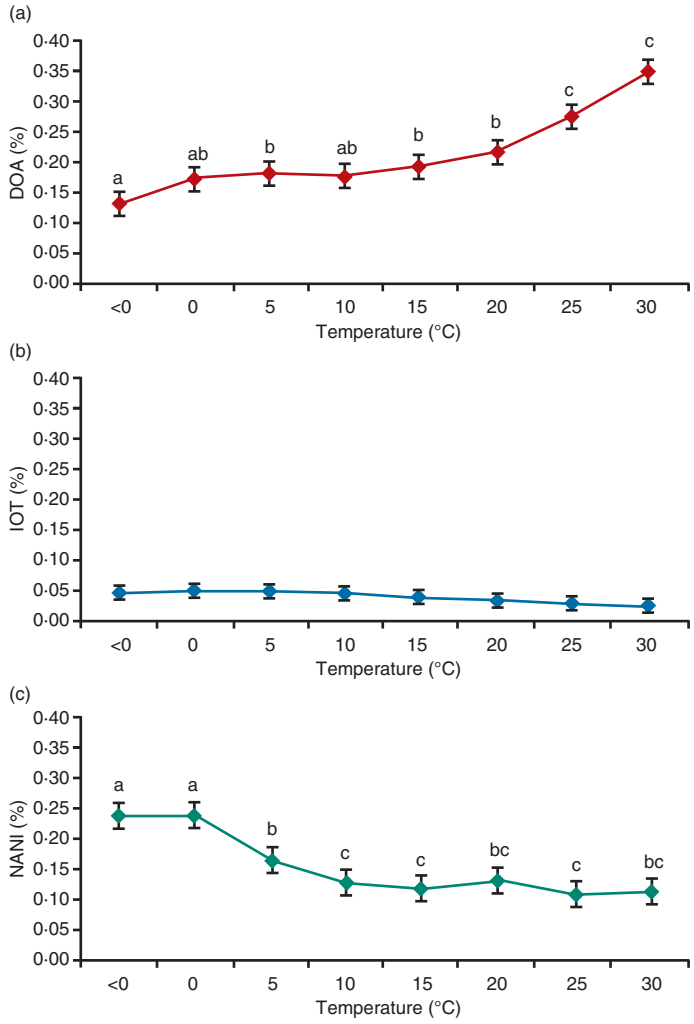

FIG 3: Least square mean (se) percentages of pigs (a) dead on arrival (DOA), (b) injured on trailer (IOT) and (c) down on trailer or before weighing (NANI) during their transport to the processing plant at different temperatures. Mean values with different letters are significantly different at P<0·05

and then decreased (r^2=0·87, P<0·01) for journeys lasting between five and 11 hours.

The waiting time at the processing plant influenced (P<0·05) the percentage of DOA, IOT, and total dead or NANI pigs (Table 2). The percentage of DOA pigs was greatest (P<0·05) at waiting times between two and three hours and over four hours. Conversely, the percentage of IOT pigs was greater (P<0·05) at waiting times less than 10 minutes than times between 20 minutes and two hours. Overall, the percentage of total dead or NANI pigs was 68·7 per cent greater (P<0·05) at waiting times over four hours than at waiting times between 10 and 29 minutes.

Effects of trailer type

The percentage of DOA and IOT pigs was affected by the interaction between trailer type and travel time. After journeys lasting three-and-a-half to four hours, the percentage of DOA pigs was greater (P<0·05) in the straight-deck trailers than in the pot-belly trailers (0·32 [0·04] v 0·18 [0·04] per cent). On journeys lasting three to three-and-a-half hours, the percentage of IOT pigs was greater (P<0·05) in the straight-deck than in the pot-belly trailers (0·05 [0·02] v 0·01 [0·01] per cent). Conversely, on journeys lasting eight to nine hours the percentage of IOT pigs was greater (P<0·05) in the pot-belly than in the straight-deck trailers (0·06 [0·01] v 0·03 [0·02] per cent). The percentage of NANI pigs was also influenced by the interaction between trailer type and travel time. On journeys lasting half an hour to one hour, the percentage of NANI pigs was greater (P<0·05) in the straight-deck than the pot-belly trailers (0·22 [0·04] v 0·08 [0·06] per cent). However, on journeys lasting one to one-and-a-half hours the percentage of NANI pigs was greater (P<0·05) in the pot-belly trailers than in the straight-deck trailers (0·42 [0·04] v 0·25 [0·03] per cent).

Effects of bedding

The percentages of DOA, IOT and NANI pigs were affected by the interaction between bedding and travel time. After journeys lasting between four-and-a-half and five hours, the percentage of DOA pigs was lower (P<0·05) in trailers with dry bedding than in trailers with wet bedding (0·20 [0·05] v 0·36 [0·06]). After journeys lasting between eight and nine hours, the percentage of IOT pigs was greater (P<0·01) in trailers with wet bedding than in trailers with dry bedding (0·16 [0·03] v 0·07 [0·02]). The percentage of NANI pigs was influenced by an interaction between bedding and month (P<0·001). In December the percentage of NANI pigs was lower (P<0·05) in trailers with dry or wet bedding than in trailers with no bedding (0·25 [0·04] and 0·15 [0·05] v 0·56 [0·13]), and in February the percentage of NANI pigs was also lower (P<0·05) in these trailers (0·17 [0·04] and 0·19 [0·05] v 0·57 [0·14]).

The percentage of NANI pigs was also influenced by an interaction between bedding and temperature (P<0·001). At temperatures of 0 to 5°C, the percentage of NANI pigs was 51·1 per cent lower (P<0·05) in trailers with dry bedding than in trailers with no bedding (0·22 [0·04] v 0·43 [0·09]). Overall, the percentage of DOA and IOT pigs was 69·8 per cent lower (P<0·05) when there was dry bedding in the trailer than

TABLE 2: Main effects of number of pigs per trailer load, waiting time at the plant, trailer type, bedding and sex on the least square mean (se) percentages of dead on arrival (DOA), injured on trailer (IOT), down on trailer or before weighing (NANI), and total dead or NANI (N&D) pigs at the processing plant. The effects were analysed using a general linear mixed model

Measure	Number of trailer loads	DOA	IOT	NANI	N&D
Pigs/trailer load					
<159	2899	0·226 (0·026)	0·045 (0·008)	0·209^{a} (0·022)	0·480^{b} (0·038)
160-164	2373	0·219 (0·026)	0·039 (0·008)	0·180^{ab} (0·023)	0·437^{c} (0·039)
165-169	2713	0·223 (0·026)	0·046 (0·008)	0·173^{b} (0·022)	0·441^{bc} (0·038)
170-174	2858	0·198 (0·026)	0·036 (0·008)	0·126^{cd} (0·022)	0·360^{d} (0·038)
175-179	1626	0·213 (0·028)	0·033 (0·009)	0·139^{d} (0·024)	0·384^{cd} (0·041)
180+	3854	0·193 (0·025)	0·038 (0·008)	0·100^{e} (0·021)	0·330^{d} (0·037)
Waiting time (minutes)					
0-9	8196	0·195^{cd} (0·013)	0·053^{c} (0·004)	0·197 (0·011)	0·445^{bc} (0·018)
10-19	791	0·145^{c} (0·026)	0·043^{cd} (0·008)	0·152 (0·022)	0·341^{c} (0·038)
20-29	978	0·177^{c} (0·023)	0·037^{d} (0·007)	0·146 (0·020)	0·361^{c} (0·034)
30-59	2143	0·171^{c} (0·017)	0·037^{d} (0·005)	0·165 (0·015)	0·373^{cd} (0·026)
60-119	2483	0·181^{c} (0·017)	0·043^{d} (0·005)	0·178 (0·014)	0·400^{bcd} (0·025)
120-179	287	0·275^{c} (0·042)	0·049^{cd} (0·013)	0·150 (0·036)	0·472^{bcd} (0·062)
180-239	60	0·266^{cd} (0·148)	0·001^{cd} (0·046)	0·073 (0·127)	0·340^{bcd} (0·218)
240+	212	0·285^{d} (0·048)	0·051^{cd} (0·015)	0·175 (0·041)	0·510^{d} (0·071)
Trailer type					
Pot-bellied	8043	0·192 (0·014)	0·052 (0·004)	0·208 (0·012)	0·452 (0·020)
Straight	8224	0·173 (0·011)	0·053 (0·004)	0·208 (0·010)	0·434 (0·017)
Bedding					
Dry	9220	0·167^{c} (0·011)	0·038^{c} (0·003)	0·255^{d} (0·009)	0·460 (0·016)
None	3359	0·204^{d} (0·016)	0·066^{d} (0·005)	0·162^{b} (0·014)	0·432 (0·023)
Wet	3711	0·177^{cd} (0·019)	0·052^{d} (0·006)	0·207^{c} (0·017)	0·436 (0·028)
Sex					
Barrow	1323	0·178^{cd} (0·022)	0·051 (0·007)	0·305^{d} (0·019)	0·535^{d} (0·033)
Gilt	1665	0·125^{c} (0·020)	0·048 (0·006)	0·173^{b} (0·017)	0·345^{c} (0·030)
Mixed	10,943	0·210^{d} (0·007)	0·051 (0·002)	0·223^{c} (0·006)	0·484^{d} (0·010)

Means in the same column with different superscripts are significantly different at P<0·05

when there was no bedding (Table 1). Conversely, the percentage of NANI pigs was 63·5 per cent greater (P<0·05) in trailers with dry bedding than in trailers with no bedding or wet bedding (Table 2).

Effects of sex

The percentages of DOA and IOT pigs were not influenced by the interactions between sex and month, temperature, number of pigs per trailer load, journey time or waiting time. However, there were interactions between sex and month (P<0·001), temperature (P<0·001), number of pigs per trailer load (P<0·001) and journey time (P<0·001) on the percentage of NANI pigs (Table 3). From January to April and in September the percentage of NANI pigs was 17·3 per cent lower (P<0·05) in trailers containing barrows than in trailers with a mixed load of pigs. At temperatures between 15 and 30°C, the percentage of NANI pigs was 14·2 per cent greater (P<0·05) in trailers with a mixed load of pigs than in trailer loads of barrows. The percentage of NANI pigs was 19·1 per cent greater (P<0·05) in mixed trailer loads of pigs than in trailer loads of barrows with between 160 and 174 pigs per trailer load. Trailers with a mixed load of pigs had a greater (P<0·05) percentage of NANI pigs than trailer loads of barrows after journeys lasting 30 to 59 minutes, 90 minutes to two-and-a-half hours, three to three-and-a-half hours, and seven to nine hours.

There was an interaction (P<0·05) between sex and trailer type for the percentage of NANI pigs (Fig 5). In pot-belly trailers, the percentage of NANI pigs was 55·5 per cent higher (P<0·05) in trailer loads of barrows than in trailer loads of gilts or mixed sexes, and in straight-deck trailers the percentage of NANI pigs was 67·3 per cent higher (P<0·05) in trailer loads of barrows and mixed sexes

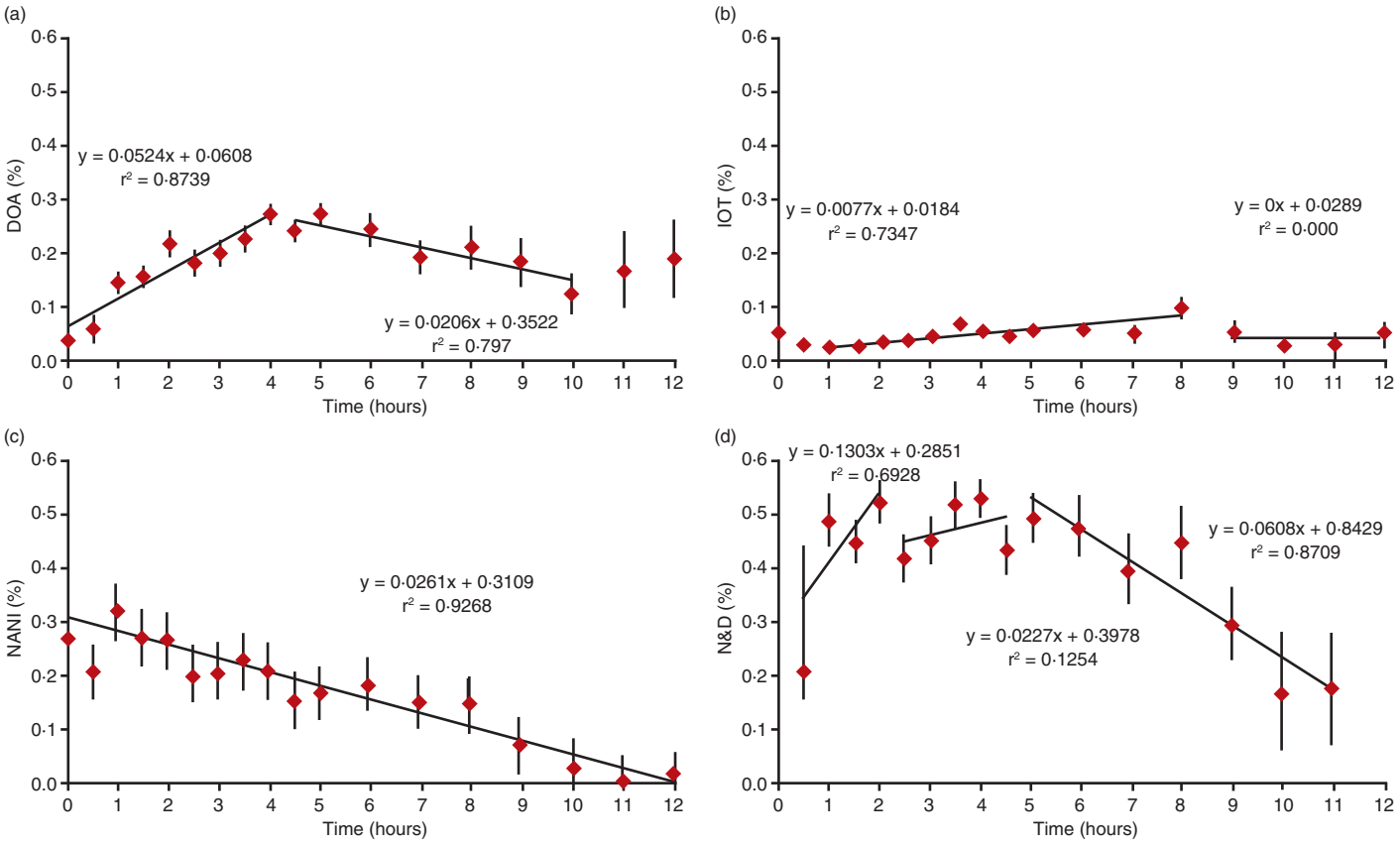

FIG 4: Least square mean (se) percentages of pigs (a) dead on arrival (DOA), (b) injured on trailer (IOT), (c) down on trailer or before weighing (NANI) and (d) dead or NANI (N&D) during their transport to the processing plant for different periods of time

TABLE 3: Least square mean (se) interactions between the sex of the pigs on the trailers and the month, ambient temperature, number of pigs per trailer, journey time to the plant and waiting time at the plant on the percentage of pigs down on trailer or before weighing (NANI) analysed using a general linear mixed model

Variable	Barrows	Gilts	Mixed sexes
Number of trailer loads	1323	1665	10,943
Month*			
January	0·000[a] (0·112)	0·029[ab] (0·106)	0·155[b] (0·030)
February	0·000[a] (0·109)	0·185[b] (0·098)	0·196[b] (0·028)
March	0·000[a] (0·104)	0·000[a] (0·097)	0·192[b] (0·027)
April	0·000[a] (0·107)	0·000[ab] (0·105)	0·150[b] (0·028)
July	0·013 (0·098)	0·095 (0·092)	0·099 (0·033)
August	0·178 (0·095)	0·089 (0·090)	0·152 (0·028)
September	0·000[a] (0·141)	0·116[ab] (0·093)	0·165[b] (0·028)
October	0·155 (0·093)	0·108 (0·087)	0·220 (0·027)
November	0·074 (0·094)	0·257 (0·094)	0·204 (0·029)
December	0·172 (0·104)	0·066 (0·099)	0·232 (0·030)
Temperature (°C)			
<0	0·070 (0·109)	0·162 (0·102)	0·270 (0·032)
0-≤4	0·280 (0·096)	0·182 (0·091)	0·238 (0·026)
5-≤9	0·060 (0·090)	0·159 (0·090)	0·176 (0·025)
10-≤14	0·000 (0·095)	0·038 (0·085)	0·160 (0·025)
15-≤19	0·000[a] (0·094)	0·064[ab] (0·088)	0·145[b] (0·026)
20-≤24	0·000[a] (0·098)	0·041[ab] (0·089)	0·153[b] (0·026)
25-≤29	0·000[a] (0·110)	0·024[ab] (0·096)	0·129[b] (0·029)
30+	0·000[a] (0·146)	0·018[ab] (0·133)	0·141[b] (0·044)
Pigs/trailer load			
<159	0·131 (0·092)	0·132 (0·084)	0·211 (0·025)
160-≤164	0·000[a] (0·093)	0·117[ab] (0·086)	0·217[b] (0·026)
165-≤169	0·000[a] (0·092)	0·097[ab] (0·087)	0·201[b] (0·025)
170-≤174	0·000[a] (0·092)	0·067[ab] (0·086)	0·155[b] (0·025)
175-≤179	0·000 (0·107)	0·073 (0·098)	0·161 (0·027)
+180	0·001 (0·095)	0·030 (0·088)	0·114 (0·023)
Travel time (hours)			
<0·5	0·436 (0·560)	0·000 (0·397)	0·296 (0·092)
0·5-≤0·9	0·000[a] (0·113)	0·206[ab] (0·097)	0·219[b] (0·033)
1·0-≤1·4	0·307 (0·085)	0·225 (0·081)	0·264 (0·029)
1·5-≤1·9	0·025[a] (0·097)	0·135[ab] (0·088)	0·305[b] (0·026)
2·0-≤2·4	0·034[a] (0·102)	0·087[a] (0·096)	0·293[b] (0·026)
2·5-≤2·9	0·000 (0·120)	0·075 (0·104)	0·212 (0·029)
3·0-≤3·4	0·000[a] (0·093)	0·161[ab] (0·091)	0·212[b] (0·025)
3·5-≤3·9	0·057 (0·096)	0·197 (0·091)	0·224 (0·027)
4·0-≤4·4	0·145 (0·093)	0·064 (0·085)	0·204 (0·023)
4·5-≤4·9	0·000 (0·109)	0·055 (0·090)	0·156 (0·029)
5·0-≤5·9	0·000 (0·117)	0·093 (0·098)	0·169 (0·025)
6·0-≤6·9	0·168 (0·145)	0·207 (0·147)	0·181 (0·030)
7·0-≤7·9	0·000[a] (0·172)	0·047[ab] (0·127)	0·165[b] (0·038)
8·0-≤8·9	0·000[a] (0·166)	0·000[ab] (0·199)	0·158[b] (0·041)
9·0-≤9·9	0·000 (0·113)	0·012 (0·124)	0·082 (0·049)
10·0-≤10·9	0·000 (0·108)	0·000 (0·107)	0·055 (0·054)
11·0-≤11·9	0·000 (0·153)	0·082 (0·162)	0·000 (0·099)
12·0+	0·000 (0·168)	0·000 (0·138)	0·023 (0·091)
Waiting time (minutes)			
0-≤9	0·154 (0·046)	0·118 (0·037)	0·206 (0·013)
10-≤19	0·036 (0·093)	0·085 (0·083)	0·177 (0·025)
20-≤29	0·000 (0·078)	0·155 (0·070)	0·174 (0·024)
30-≤59	0·054 (0·061)	0·072 (0·053)	0·187 (0·017)
60-≤119	0·110 (0·062)	0·090 (0·049)	0·197 (0·016)
120-≤179	0·003 (0·151)	0·017 (0·099)	0·195 (0·041)
180-≤239	0·000 (0·552)	0·113 (0·555)	0·117 (0·134)
240+	0·221 (0·127)	0·038 (0·139)	0·158 (0·050)

* Sex of pigs not available for May or June
Means in the same row with different superscripts are significantly different (P<0·05)

FIG 5: Least square mean (se) percentages of barrows, gilts or mixed loads of pigs that were down on trailer or before weighing (NANI) after their transport to the processing plant in either pot-belly or straight-deck trailers. For each type of trailer, mean values with different letters are significantly different at P<0·05

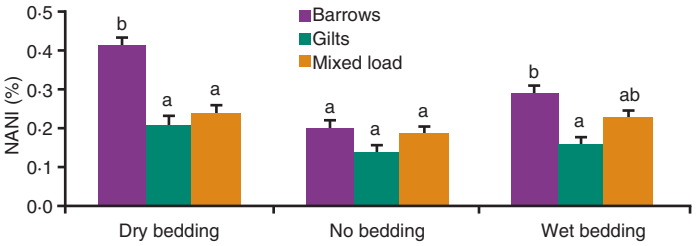

FIG 6: Least square mean (sd) percentages of barrows, gilts or mixed loads of pigs that were down on trailer or before weighing (NANI) after their transport to the processing plant on dry or wet bedding or with no bedding. For each type of bedding, mean values with different letters are significantly different at P<0·05

than in trailer loads of gilts. There was an interaction (P<0·05) between sex and bedding for the percentage of NANI pigs (Fig 6). In trailers with dry and wet bedding, the percentage of NANI pigs was 60·6 per cent greater (P<0·05) in trailers of barrows than in trailers of gilts.

Discussion

The objective of this study was to record a range of variables that might affect the percentage of dead and NANI pigs during journeys to a slaughterhouse. It was a retrospective study, and the findings need to be used to develop hypotheses for controlled studies to test them. Because the data from a large number of trailer loads of pigs were analysed, it is likely that the largest effects, for example, of temperature, month and duration of the journeys, will be repeatable in controlled field studies. One of the limitations of a retrospective study is the absence of some data. Many variables that were not measured might have influenced the percentage of dead and NANI pigs, including the handling of the pigs at loading, their health and their space allowance on the trailers.

The percentages of DOA and NANI pigs were recorded over a period of 12 months. The percentages increased from July to December, a period during which the average monthly temperature decreased, suggesting that the effect of month on transport loss was due solely to the effect of temperature. Data collected from 7396 trailer loads and 1,303,148 pigs transported to 37 different processing plants in the USA showed a similar trend, with the percentage of NANI pigs increasing from June to July and peaking in November (Rademacher and Davies 2005). One possible explanation for this phenomenon could be the higher average weight of the pigs and therefore the higher density of pigs per trailer load due to the greater nutritional value of new corn in combination with the increased daily weight gain associated with cooler temperatures. The total weights of the pigs on each trailer were not recorded and controlled studies are therefore needed to investigate this finding. In the UK, a survey of transport losses showed that there were more DOA losses during the hotter summer months (Warriss and Brown 1994), suggesting that some of the factors that influence transport losses in the USA may differ from those affecting losses in the UK. In the USA, factors other than temperature may affect the transport losses of pigs each month.

Temperature had opposing effects on the percentages of DOA and NANI pigs. The percentage of DOA pigs increased at temperatures above 20°C, in agreement with the findings of Rademacher and Davies (2005) in the USA, Dewey and others (2006) in Canada, and Smith and Allen (1975), Warriss and Brown (1994) and Lambooij (2000) in Europe. The percentage of NANI pigs decreased as the temperature increased above 0°C, in agreement with Rademacher and Davies (2005) who found that the percentage of NANI pigs did not increase with temperature. The increase in DOA pigs as the temperature increased may account for the decrease in NANI pigs at high temperatures, because pigs that might have become NANI pigs at lower temperatures may die at temperatures above 20°C. Pigs maintain their body temperature constant by balancing heat loss and heat production through mechanisms such as eating, evaporative cooling and huddling (Lambooij 2000). Pigs seem able to maintain their

body temperature more easily at low temperatures than at high temperatures, by such mechanisms as huddling and shivering (Schrama and others 1996). If pigs are unable to lose heat quickly enough, either by changes in behaviour or other means, during journeys in high temperatures they are likely to become hyperthermic and may die. In this study, temperature was recorded only when the trailer arrived at the processing plant, and the temperature in the trailer could have varied considerably, depending on the length of the journey and the time of day the pigs were transported. Furthermore, the temperature inside the trailer is not necessarily related directly to the outside temperature. Controlled field studies are needed to determine the effect of the temperature inside trailers on the losses of pigs being transported.

The relative humidity did not influence the percentage of DOA or NANI pigs. Smith and Allen (1975) also found that changes in humidity did not influence the number of pigs dying while being transported. However, irrespective of the external humidity, the humidity inside the trailer is likely to approach 100 per cent when the truck stops, and this would reduce the ability of the pigs to use evaporative cooling as a mechanism of heat loss. As a result, air movement is critical for pigs in trailers if they stop for more than a few minutes.

The travel time and waiting time at the processing plant affected the percentages of DOA and NANI pigs. The percentage of DOA pigs increased as the journey time increased from 30 minutes to 4 hours. A high mortality risk was also recorded in pigs transported for between 30 and 90 minutes in the study by Rademacher and Davies (2005). Pigs that die during the first few hours of a journey may have become so stressed during loading and the early stages of the journey that they are unable to recover. After pigs have been handled intensively it takes approximately two hours for their physiological parameters to return to baseline (Hemsworth and others 2002, Hamilton and others 2004); pigs transported for short periods may therefore have insufficient time to recuperate from the stress of loading, resulting in increased losses during this period. During journeys lasting more than four hours, the percentage of DOA pigs decreased. Rademacher and Davies (2005) also found that journeys lasting more than three hours had a minimal effect on the losses of pigs. Longer journeys may give pigs that have been stressed when being loaded on to the trailer time to rest and recover, so that they do not become NANI. The critical journey time in relation to dead and NANI pigs appears to be up to four hours.

The percentage of DOA pigs increased as the waiting time at the processing plant increased, with the highest losses occurring at waiting times over four hours. To minimise losses of pigs at this stage of production, waiting times should therefore be less than four hours.

The sex of the pigs in the trailers had a significant effect on the percentage of NANI pigs. The percentages of NANI pigs were generally greater in trailer loads of barrows or mixed sexes than gilts, regardless of the month, temperature, number of pigs per trailer and journey time. Mixing unfamiliar pigs at the farm often causes fighting to establish new dominance orders. Fighting can cause stress, and possibly fatigue, as indicated by increased concentrations of cortisol and creatine phosphokinase, and evidence of muscle glycogen depletion (Warriss 1995). However, slaughter weight pigs stand (Bradshaw and others 1996) or lie down (Lambooy 1988) while being transported. Differences between the bodyweights, metabolic rates or energy reserves of the sexes may contribute to the effects observed on the rate of NANI pigs. Keeping the sexes separated from each other on mixed trailer loads could reduce the percentage of dead and NANI pigs.

The type of trailer and the presence of bedding affected the percentages of DOA and NANI pigs, and the type of trailer and journey time affected the percentages of DOA, IOT and NANI pigs. The percentage of NANI pigs was affected by the absence or presence of bedding and whether it was dry or wet, and the effects depended on the month, temperature and sex of the pigs in the trailer. Bedding is recommended to prevent the pigs from slipping or falling, and to provide comfort, especially in cold weather. However, the presence of bedding, especially if it is wet, may be detrimental rather than beneficial. For example, in cold weather, the percentage of NANI pigs was 57 per cent higher in pot-belly trailers transporting trailer loads of barrows when there was either dry or wet bedding than when there was none. The types of trailers were categorised as straight-deck, pot-belly or other. However, within these categories there are many variations depending on the make and model of the trailer. For example, their length ranged from 14·7 to 16·2 m and they had either punched-out sides or slatted sides. Differences in trailer construction could potentially influence ventilation and therefore temperature and humidity within the trailer, and the space allowance for the pigs. Controlled studies are needed to assess the effect of particular trailer types on pig losses during transport.

Many factors, including genetics and their handling before they are transported may be associated with the percentages of dead and NANI pigs during their journey to the slaughterhouse. However, conditions during the journey are also a major factor. Conditions that increase the numbers of DOA and NANI pigs are likely to affect their welfare adversely. Temperatures below 5°C (especially when there is no bedding in the trailer) and above 20°C, journeys lasting 30 minutes to four hours, waiting times at the processing plant longer than four hours, journeys during October, November and December, and transporting trailer loads of pigs of both sexes were all factors that could adversely affect the welfare of pigs being transported to slaughter. Furthermore, these factors did not necessarily affect the percentage of DOA and NANI pigs in the same way. However, other variables that were not measured may have also influenced the percentage of DOA and NANI pigs. These data can be used to develop hypotheses for controlled studies aimed at reducing the percentage of DOA and NANI pigs and improving the welfare of pigs being transported to slaughter.

During times when there is a high risk of DOA and NANI pigs, extra measures should be taken to reduce the risk. For example, in the summer, pigs could be transported during the cooler times of the day, and in the winter they could be provided with bedding and the trailers could be boarded; whenever possible, transporting trailer loads of pigs of both sexes should be avoided.

Acknowledgements

The authors thank Paul Dubois, Steve Pirkle, and Rachelle Hardage for their technical help and support. A major US pork processing plant was instrumental in the collection of data.

References

BRADSHAW, R. H., PARROTT, R. F., GOODE, J. A., LLOYD, D. M., RODWAY, R. G. & BROOM, D. M. (1996) Behavioural and hormonal responses of pigs during transport: effect of mixing and duration of journey. *Journal of Animal Science* **62,** 547-554

DEWEY, C. E., HALEY, C., WIDOWSKI, T. & FRIENDSHIP, R. M. (2006) In-transit mortality in finisher pigs in Ontario swine. Proceedings of the International Pig Veterinary Society Congress. Copenhagen, July 16 to 19, 2006. p 603

ELLIS, M., MCKEITH, F., HAMILTON, D., BERTOL, T. & RITTER, M. (2003) Analysis of the current situation: what do downers cost the industry and what can we do about it? Proceedings of the 4th American Meat Science Association Pork Quality Symposium. Columbia, June 15 to 19, 2003. pp 1-3

HAMILTON, D. N., ELLIS, M., BERTOL, T. M. & MILLER, K. D. (2004) Effects of handling intensity and live weight on blood acid-base status in finishing pigs. *Journal of Animal Science* **82,** 2405-2409

HEMSWORTH, P. H., BARNETT, J. L., HOFMEYR, C., COLEMAN, G. J., DOWLING, S. & BOYCE, J. (2002) The effects of fear of humans and pre-slaughter handling on the meat quality of pigs. *Australian Journal of Agriculture Research* **53,** 493-501

LAMBOOIJ, B. (2000) Transport of pigs. In Livestock Handling and Transport. 2nd edn. Ed T. Grandin. CAB International. pp 275-296

LAMBOOY, E. (1988) Road transport of pigs over a long distance: some aspects of behaviour, temperature and humidity during transport and some effects of the last two factors. *Animal Production* **28,** 163-174

PEETERS, E., DRIESSEN, B., STEEGMANS, R., HENOT, D. & GEERS, R. (2004) Effect of supplemental tryptophan, vitamin E, and a herbal product on responses by pigs to vibration. *Journal of Animal Science* **82,** 2410-2420

RADEMACHER, C. & DAVIES, P. R. (2005) Factors associated with the incidence of mortality during transport of market hogs. Proceedings of the Allen D. Leman Swine Conference. St Paul, September 17 to 20, 2005. pp 186-191

SCHRAMA, J. W., VAN DER HEL, W., GORSSEN, J., HENKEN, A. M., VERSTEGGEN, M. W. A. & NOORDHUIZEN, J. P. T. M. (1996) Required thermal thresholds during transport of animals. *Veterinary Quarterly* **18,** 90-95

SMITH, L. P. & ALLEN, W. M. (1975) A study of the weather conditions related to the death of pigs during and after their transportation in England. *Agricultural Meteorology* **16,** 115-124

WARRISS, P. D. (1995) Pig handling: guidelines for the handling of pigs antemortem. *Meat Focus International* **4,** 491-494

WARRISS, P. D. & BROWN, S. N. (1994) A survey of mortality in slaughter pigs during transport and lairage. *Veterinary Record* **34,** 513-515