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Factors associated with in-transit losses of fattening pigs

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Abstract

In-transit losses (ITL) in fattening pigs refers to mortality occurring after having left the farm but prior to stunning at the abattoir. The purpose of this observational study was to identify the associations between environmental and truck temperatures, distances travelled, feed withdrawal, farm, transport company and abattoir and in-transit losses of fattening pigs marketed in Ontario, Canada from 2001 to 2004. A prospective study of 104 trips was conducted to determine temperatures inside the truck and identify the factors associated with this. In 2001, ITL was 0.017%, with 75% of producers losing < 5 pigs annually. In-transit losses increased between distances travelled of 590 to 720 km and decreased at distances greater than 980 km. The Pig Comfort Index, a combination of temperature and humidity, was used to identify thresholds of environmental conditions above which in-transit losses increased. The farm at which the pig was raised explained more variation of ITL (25%) than transport company (8%) or abattoir (16%). The within-farm ITL in 2003 had a positive association with those in 2001 and 2002. Withdrawing food prior to transport may decrease ITL on some farms. The temperature in truck compartments holding pigs increased by 0.99°C as the environmental temperature increased by 1°C and by 0.1°C as the relative humidity increased by 1%. Truck temperature decreased 0.06°C for each increase in driving speed of 10 km h^{-1} and increased by 7°C with an increase in pig density from one to 2.6 pigs per m^2.

Keywords: *animal welfare, epidemiology, in-transit loss, mortality, pig, transport*

Introduction

In-transit loss in pigs is a term used to describe death that occurs after the pig has left the farm but before it has been stunned at the abattoir. In-transit losses range from 0.07 to 1.5% of finishing pigs (Allen *et al* 1974; van Logtestijn *et al* 1981; Warris 1998b; Whiting & Brandt 2002). Although these mortality rates are low, the actual numbers of pigs that die annually, around the world is significant and the welfare implications serious. Factors associated with in-transit losses in previous studies include high environmental temperature and humidity, high stocking density and either short or long trip duration. Farm-level factors associated with in-transit loss include pre-market status in terms of hydration and feed withdrawal, illness, and genetics (Warriss *et al* 1991; Labooij & van Putten 1993; Hunter *et al* 1994; Abbott *et al* 1995; Bradshaw *et al* 1996; Warriss 1998a; Whiting & Brandt 2002). Pigs that are transported shortly after having consumed feed are prone to vomiting, which has an association with in-transit losses (Riches *et al* 1996). Further, in-transit losses are also associated with the loading of pigs up steep ramps and/or the use of electric prods during loading (Guise & Penny 1989).

When in-transit loss occurs, it is likely that the transport conditions associated with the deaths of certain pigs also caused physiological stress to others in the load, possibly compromising the quality of the pork from these pigs. The environmental and pig handling conditions that are associated with the death of pigs are also associated with fatigued pigs (Geers *et al* 1994).

Although extensive research has been conducted on in-transit loss, the majority of the work has been done under commercial conditions in Europe. Limited information exists about transport conditions and in-transit loss in Canada and none reflecting the conditions in Ontario. Data are recorded for every finisher pig raised in Ontario, Canada and then transported to an abattoir.

The objectives of this study were to determine the following: the associations between in-transit loss and distance travelled and environmental conditions as measured by the Pig Comfort Index (PCI) after controlling for farm, transporter and abattoir; the variation of in-transit losses by each phase of transport (farm, truck, abattoir); the temperature inside the truck during transport of fattening pigs; the associations between environmental temperature and humidity during transport; the space provided per pig (measured in pigs per m^2), the distance travelled, the speed and the time the truck was stopped; whether farm-level, in-transit losses one year were associated with in-transit losses the following year; the association between in-transit loss and the temperature and humidity inside the truck, the space provided to the pig (measured in pigs per m^2) and the distance or speed travelled and whether withholding feed prior to transport would reduce in-transit losses in four commercial herds.

Materials and methods

This study was approved by the Animal Care Committee of the University of Guelph. A pig was considered to have died in-transit if the death occurred after leaving the farm but before being stunned at the abattoir. The three phases of transit identified were farm, truck and abattoir. The truck was classified according to the transport company (transporter) rather than the individual truck or truck driver. In-transit loss ratios (ITLR) were calculated as the number of pigs which died in-transit, divided by the number of pigs marketed per producer per day. The number of pigs marketed per producer per day transported on one truck and sent to one abattoir was used as the animal-time component to calculate the incidence death rate. This group of pigs was called a 'lot' of pigs. For the transporters and abattoir, the denominator was the number of pigs transported or received, respectively.

Study one

The objective of this study was to determine the association between in-transit loss and distance travelled and environmental conditions as measured by the PCI after controlling for farm, transporter and abattoir. Census data was utilised for this study, including information about each lot of pigs shipped by each producer in Ontario in 2001. All market weight pigs in Ontario are sold through the Ontario Pork Producers' Marketing Board (Ont Pork). A paper and a computer record of each lot of pigs are kept by Ont Pork. These data were used to pay the producer for the pigs marketed. Each observation included, date of shipment, producer's identification number, number of pigs shipped by that producer, number of subject pigs in the group, number of pigs in the group that died in-transit, phase of transport when pigs died, transporter, abattoir and expected time of arrival at the abattoir. The phase of transport during which the pig died was considered responsible for the death unless it had been recognised as being abnormal at an earlier phase. If a pig had a clinical problem at any phase of transport, it was recorded as a subject pig. If that pig subsequently died, the phase of transport when it was first identified as being abnormal was considered responsible for the death. The data received from Ont Pork were validated by comparing the digital data to the paper records. Hourly temperature and relative humidity measurements were obtained from six weather stations located geographically close to the abattoirs in Ontario and Quebec and the United States receiving market pigs from Ontario (Environment Canada; National Oceanic and Atmospheric Administration). A temperature-humidity index called a pig comfort index (PCI), based on the expected impact of temperature and humidity on pigs, was calculated as 0.75 (dry temperature) + 0.25 (wet temperature) (Roller & Goldman 1969). Weather data were merged with the data from Ont Pork by the abattoir and the hour of delivery of the pigs to the abattoir using the SAS software package (SAS version 8.2; SAS Institute, Cary, NC, USA). Distance travelled by pigs was estimated by determining the distance between the transport company dispatching yard and the abattoir. The number of kilometers between the two sites was determined using the distance function in Mapquest® by inserting postal codes or zip codes for Canadian and United States destinations, respectively. Distance information was merged with the in-transit loss data on the basis of transporter and abattoir information.

Study 2

The objective of this study was to determine whether farm-level, in-transit losses in one year were associated with in-transit losses the following year: all 3,434 farms that marketed at least 21 pigs in 2001, 2002 and 2003 in Ontario were included in the study.

Study 3

The objective of this study was to determine whether withholding feed prior to transport would reduce in-transit losses in four commercial herds that had losses that were higher than industry averages in the previous calendar year. This prospective cross-over field trial included four commercial farms, located in south-western Ontario that had a history of high in-transit losses. In the first week, two farms were randomly assigned to the feed withdrawal treatment while the other two farms were in the full feed treatment group. The following week, the farms reversed the treatment. Every other week, for 16 weeks, the pigs that were marketed were exposed to feed withdrawal and then full feed. During the feed withdrawal weeks, pigs that were to be marketed were put in a holding pen without feed for 8 h prior to transport. In the full feed weeks, pigs were left in their home pen and fed *ad libitum* until they were moved onto the truck for transport.

Study 4

The first objective was to determine the association between the temperature inside the truck and the environmental temperature and humidity during transport, the space provided per pig (measured in pigs per m^2), the distance travelled, the speed and the time the truck was stopped. The second objective was to determine the association between in-transit loss and the temperature and humidity inside the truck, the space provided to the pig (measured in pigs per m^2) and the distance or speed travelled.

This prospective study included three transport companies in Ontario that volunteered to participate in this study. There were four sizes of three-tiered trucks and nine drivers who participated in the study. This distribution of companies, trucks and drivers was included to determine whether losses were associated with any of these factors. Trucks were equipped with probes to measure the temperature and relative humidity (HOBO™, Onset Computer Corporation, Bourne, MA, USA) that were affixed to the ceiling of three compartments in the truck where pigs were housed. This was 120, 60 and 15 cm above the heads of the pigs in the top, back and bottom compartments of the truck, respectively. Although the temperature at that height may have differed somewhat from that which the pig experienced at the height of its body, it was crucial that the pigs were not able to reach up and destroy the probe. Although not measured, we expect that the temperature in the top compartment may have been lower than that experienced by the pigs because there was 120 cm of air space for cooling. A global positioning system (GPS) (Turnpike Global Technologies, Stoney Creek, Ontario, Canada) was placed in the cab of the truck to measure speed and stopping times. Complete temperature and GPS information was collected for 104 trips from July to October 2004. These data were merged with one-minute environmental temperature from weather stations nearest the abattoir.

Statistical analysis

Study 1

The in-transit loss ratio at the producer level was the dependent variable for modelling associations among putative causative factors and the death of pigs, in-transit, using zero inflated models. Initially, simple associations between in-transit loss and the independent variables of interest were determined. These included, number of pigs marketed per producer in increments of 500 pigs and distance travelled in increments of 50 km. Quadratic and cubic functions of these variables were also tested and retained in the model if $P < 0.05$. Hierarchical dummy variables were created for the PCI variables to identify specific thresholds of this index at which losses increased significantly, compared to the previous index (Walter *et al* 1987). This model was built using a backward selection process, eliminating the variable with the highest P-value at each step. All variables significant at $P < 0.05$ were entered into a multivariable model with other significant fixed effects and potential interaction terms based on these variables. A backward elimination process was used to remove non-significant variables ($P > 0.05$). The fixed effect models were analysed and tested for goodness of fit, outliers, and leverage using Stata Statistical software, Release 7.0 (Stata Corporation, College Station, TX, USA). A Poisson general linear mixed effects model using a Glimmix macro in SAS was performed, including the significant fixed effects and the random effects of producer, transporter and abattoir. Variables with $P > 0.05$ were eliminated from these models. The variation of in-transit losses by each phase of transport was compared using the random effects coefficients.

Study 2

The in-transit losses, from 2003, were regressed on the losses in 2002 and 2001 using linear regression with a robust option to neutralise inherent non-constant variance.

Study 3

The average within farm, in-transit losses were described by treatment.

Study 4

Trailer temperatures were regressed on the following fixed effects; density (pigs per m^2), average speed between observations (km h^{-1}), external dry temperature, and relative humidity (RH). Polynomial terms for each fixed effect were also assessed. Significant simple associations were identified ($P < 0.05$), and these variables were included in the multivariable model. Final models were developed using a backward elimination selection process (Dohoo *et al* 2003). The models were built using a robust variance estimate to combat inherent heteroscedasticity (Long & Ervin 2000). The fixed-effect models were built and tested for goodness of fit, outliers, and leverage using STATA software (Stata Corporation, College Station, TX, USA). The significant fixed effects were included in mixed models with trip number, truck, and trucking company as random variables in the longitudinal data, using Proc Mixed in SAS version 8.2 (SAS Institute Inc, Cary, NC, USA). Random effects not significant at the 5% level were eliminated.

Results

Study 1

The data from 2001 included 4,159 producers, 33 abattoirs and 117 transport companies representing 4,760,213 market pigs transported on 329 separate days. Of these pigs, 7,969 or 0.17% died in transit. There were 1,212 pigs (0.025%) classified as subject that died. These represented 15% of the pigs that died. Producers which ship less than 2,000 pigs had higher losses than those shipping more. Approximately 65% of producers shipped less than 500 pigs. Most producers (75%) which lost a pig in-transit lost fewer than six pigs during the year. Approximately 74% of all shipments to the abattoir involved a distance greater than 200 km. Distance alone was not associated with the incidence of in-transit deaths or subject classification.

For the PCI hierarchical ranges, the incidence rate for pig deaths within that range is approximately the coefficient × the incidence rate for pig deaths in the range below it. For example, for the first range, the incidence rate for pig deaths between indexes of 10 to 14 is approximately 1.11 times greater than the incidence rate for pig deaths in below that range when controlling for all other fixed covariates in the model and the average random effects of producer, transporter, and abattoir (Table 1). Coefficients of hierarchical variables are additive. The incidence rate of in-transit losses for pigs shipped at 26 to 31°C is 8.5 times that of pigs that are shipped when the temperature is less than 10°C.

Approximately 56% of pigs that died in-transit are found dead on the truck. However, the farm where the pig was raised was associated with a higher proportion of the random variation of in-transit losses than the transporter. The highest level of variance based on the clustering of pigs was at the farm level. This represented 25.2% of the total random variation of in-transit loss. The abattoir explained 16.4% of the random variation and the transport company explained only 16.4% of this random variation.

Table 1 Factors associated with in-transit loss ratio for Ontario market pigs in 2001, with impact measured as incidence rate ratio (IRR) based on a Poisson general linear mixed random effects model.

Fixed effect	IRR[a]	SE	*P*-value
Pig Comfort Index[b]			
10 to < 14	1.13	0.203	< 0.0001
14 to < 16	1.25	0.046	0.01
16 to < 19	1.24	0.064	< 0.001
19 to < 22	1.56	0.061	< 0.001
22 to < 26	1.26	0.048	< 0.0001
26 to < 32	2.06	0.044	< 0.0001
32 to < 33	1.48	0.046	< 0.0001
33 to 33.6	0.13	0.122	
Pigs marketed (500-pig increments)	1.02	0.357	< 0.0001
Pigs marketed[2] (500-pig increments)	1.00	0.014	0.21
Pigs marketed[3] (500-pig increments)	1.00	0.001	0.02
Distance (50-km increments)	1.13	< 0.001	0.01
Distance (50-km increments)[2]	1.00	0.031	< 0.001
Random effect	Variation due to random variables		
Producer[c]	0.54	0.029	< 0.0001
Transporter[c]	0.17	0.044	< 0.0001
Abattoir[c]	0.35	0.132	< 0.01
Error term	1.08	0.004	< 0.0001

[a] Incidence rate ratio (IRR): for a given hierarchical range of PCI, the incidence rate for death is approximately the IRR × the incidence rate of death for next lower range.
[b] PCI = 0.75 (dry-bulb temperature in °C) + 0.25 (wet-bulb temperature °C) (Roller & Goldman 1969).
[c] Producer, transporter and abattoir included in the model as random variables.
[2] The squared term for pigs marketed; [3] the cubed term for pigs marketed.

Study 2

The in-transit losses on a farm in one year were associated with those in previous years. As losses in 2001 increased by 1%, losses in 2003 increased by 0.10% (P = 0.4). Similarly, as losses in 2002 increased by 1%, losses in 2003 increased by 0.16% ($P < 0.001$).

Study 3

There was not a consistent reduction in in-transit losses due to feed withdrawal. On two farms, in-transit losses were numerically smaller during the feed withdrawal weeks (0.19 and 0.11%, respectively) than in the full feed weeks (0.87 and 0.36%). Whilst on the other two farms, the in-transit losses were 0.25 and 0.3% in the feed withdrawal weeks, but no pigs died in transit during the full feed weeks.

Study 4

This study included 21,834 pigs transported by nine drivers during 104 trips from July to October 2004. The 90th percentile of temperature in the trucks was 26.3ºC. The average temperature increase on trucks waiting to unload at the abattoir was 5.4°C. The in-transit loss averaged 0.12% and was experienced by only 21 of the 370 farmers in the study. The average pig density was 2.52 pigs m^{-2}, but this ranged from 1.78 to 3.23 pigs m^{-2}.

As the environmental temperature increased by 1°C, the internal truck temperature increased by 0.99°C ($P < 0.001$) (Table 2). As the environmental humidity increased by 1%, the internal truck temperature increased by 0.11°C ($P < 0.001$). There is a sparing effect of the interaction between environmental temperature and humidity. As this interaction term increased by one unit, the internal truck temperature decreased by 0.004°C ($P < 0.0001$).

As trailer temperature increased, in-transit losses also increased (Table 3). In-transit losses increased three times as the 90th percentile of in-trailer temperature increased from 8.6–23.3 to 23.4–26.1ºC. It also doubled from 26.2–28.9 to 29.0–30.5ºC. As the 90th percentile of temperature increased by 1ºC, the in-transit loss increased 1.26 times. Herd size was not associated with in-transit loss. Neither the truck driver nor the transport company were associated with in-transit losses. However, trip number explained 96 to 97% of the variation in in-transit loss not accounted for by trailer temperature and distance travelled. The length of the trip was associated with a reduction in in-transit losses. For every 50 km increase in distance, in-transit losses were expected to decrease 0.81 times. The level of humidity on the trailers was not associated with in-transit loss after controlling for trailer temperature and distance travelled.

Discussion

In 2001, there were 4.7 million pigs marketed in Ontario and, of these, 16.7 pigs per 10,000 died in-transit. This ratio of in-transit losses is similar to those of other studies in which the losses ranged from 0.08 to 0.15% (Allen *et al* 1974; Clark 1979; van Logtestijn *et al* 1981; Warris 1998b; Whiting & Brandt 2002). Studies of this type have been conducted in the USA, but were limited to individual abattoirs or trucking companies (Zanella & Duran 2001).

In-transit losses were highest as the environmental temperature and humidity increased in the summer months (Haley *et al* 2008a). Other researchers have found an association between high temperatures and in-transit loss (Allen *et al* 1974; Smith & Allen 1976; Lambooy & Engel 1991). The combination of high temperature and high humidity reduces the ability of pigs to dissipate body heat effectively through radiative, convective, or evaporative means (Curtis 1983). Under these conditions, core body temperature cannot be regulated and metabolic acidosis and cardiovascular failure ultimately develop. The PCI is a combination of the environmental temperature and humidity and is meant to reflect the pig's ability to regulate body temperature (Roller & Goldman 1969). Pigs do not sweat sufficiently to cool themselves; therefore, without an external source of water for evaporation from body surfaces, they must rely exclusively on panting for evaporative cooling. Respiratory evaporation is generally less affected by relative humidity than is evaporation from external skin surfaces. Thus, in contrast to humans, pigs are more sensitive to high dry temperature than high humidity. There were several PCI thresholds associated with increasing in-transit loss ratios. At a relative humidity of 60%, the incidence rate of predicted deaths in-transit was 5.9 times higher at 26 to 31°C than at 16 to 18°C (Haley *et al* 2008a). Transporting pigs during the night and reducing pig density on trucks might reduce in-transit deaths during extremes of temperature and humidity.

Previous research suggests that the upper critical temperature in a maintenance-fed, fasted market pig is 23 to 31°C (Lambooy & van Putten 1993). In the summer of 2004 in Ontario, the average internal trailer temperature for the 104 loads of pigs exceeded 23°C 49% of the time and exceeded 31°C three percent of the time (Haley *et al* 2008b). There was an interaction between the temperature inside the truck and the outside environmental temperature and humidity. When environmental temperature was low, RH had a higher impact on internal temperature. Air with a higher RH has a greater proportion of its heat contained as latent heat of evaporation, so it feels warmer than its dry bulb temperature. When warm air has a high RH, pigs increase heat dissipation methods. At higher temperatures, most of this is accomplished by evaporative loss, which is compromised when RH is high. If the temperature is < 30°C, pigs survive humidity up to 97% but when the temperature is over 30°C, a humidity of more than 87% causes physiological stress (Randall 1993). This is likely to explain why temperature within the truck was positively associated with in-transit loss but humidity inside the truck was not (Table 3) (Haley *et al* 2008b).

Farm management factors are key components in reducing the overall industry losses. This was identified in three ways. First, there were many farms in 2001 that did not experience any in-transit losses, whereas others had significant losses. Further, the farm of origin explained more of the total random variation of in-transit loss (25%) than either abattoir (16%) or transporter (16%). This indicates, for example, that a transport company can truck pigs from one farm and they will die but can also truck pigs from another farm and they will live. Even though the pigs tend to die on the truck, it is the differences in source of pigs rather than the differences in trucks or trucking company that explain the loss. Finally, the fact that losses in one year were positively associated with the losses in subsequent years highlights the importance of the manner in which we raise fattening pigs and handle them as we load them out of the barn and move them onto the truck. Further research has identified several potential sources of this effect including high lean genetics, handling techniques, moving strategies, shipping procedures and facilities, feed restriction, degree of mixing of the pigs transported (Warriss *et al* 1991; Geers *et al* 1994; Warriss 1998; Beattie *et al* 2000; de Jong *et al* 2000). Although the farmer and the abattoir have access to carcase characteristics, that information was not available to the researchers. None of the farm-level factors were examined in these studies other than feed withdrawal prior to loading. A small field trial conducted over 16 weeks on four farms yielded inconclusive evidence of the association between feed withdrawal and in-transit losses. This management practice was associated with

Table 2 Factors associated with temperatures inside trucks transporting market pigs in Ontario in the summer of 2004.

Fixed effect	Coefficient	SE	*P*-value
Intercept	4.13	0.66	< 0.0001
Speed/10	–0.06	0.003	< 0.0001
Pigs per m²	–19.38	0.89	< 0.0001
Pigs per m²)²	13.84	0.55	< 0.0001
Pigs per m²)³	–2.52	0.105	< 0.0001
Environmental temperature[a]	0.99	0.018	< 0.0001
Environmental humidity	0.11	0.005	< 0.0001
Environmental temperature × humidity	–0.004	0.001	< 0.0001
Random effects			
Trip	3.84	0.54	< 0.0001
Error term	7.16	0.04	< 0.0001

[a] Based on the average temperature recorded from three locations on the trailer during 52,293 one-minute intervals which account for the cumulative distance travelled by 104 trips.
Trailer temperatures in the longitudinal database were regressed on fixed effects and the random effects of trucking company, truck and trip using Proc Mixed in version 8.2 (SAS Institute Inc, Cary, NC, USA).

Table 3 Associations between in-transit losses and the 90th percentile of internal trailer temperature and distance travelled for 104 loads of Ontario market pigs in 2004.

Factor	90th percentile		
	IRR[b]	SE	*P*-value
Fixed effects			
Intercept	0.00	2.334	< 0.0001
Temperature[a]	1.26	0.085	0.007
Distance in 50 km increments	0.81	0.045	< 0.0001
Random effects	**Value**		
Trip number	4.76	0.994	< 0.0001
Error term	0.22	0.013	< 0.0001

[a] The temperature is the average temperature measured from three areas in the truck.
[b] The Incidence Rate Ratio (IRR) indicates the change in in-transit loss for every 1°C increase in temperature or 50 km increase in distance travelled.

reduced losses in only two of the farms. It is likely that feed withdrawal is one factor associated with losses on specific farms but there are many other potential causative factors. Implementing feed withdrawal on farms with high losses is a worthwhile management change.

Previous research has suggested associations between carcase quality compromise and behaviour and short trips (1 to 4 h), moderately long trips (4 to 8 h), and extremely long trips (> 24 h) (Lambooy 1983; Abbott *et al* 1995; Bradshaw *et al* 1996). Losses increased sharply between 590 and 720 km and then remained fairly constant until 980 km at which point the losses decreased. Distance travelled seems to have a protective effect in trips of approximately 10 h or more (980 to 1,100 km) (Haley *et al* 2008a). Similarly, the temperature inside the truck decreased as the speed increased by increments of 10 km h^{-1}. After controlling for the temperature inside the truck, distance had a sparing effect on the in-transit loss (Haley *et al* 2008b). As the distance increased by 50 km units, the in-transit loss ratio decreased by 0.81 (Table 3). High travelling speeds will increase the flow of air over the pigs, they are cooled and therefore dissipate heat. Typically, long distances in Canada are associated with high speed travel on highways.

There was a curvilinear association between pig-density changes and the temperature inside the truck. As the number of pigs per square meter increased, the internal temperature increased at an increasing rate. Similarly, in a previous study, when pig density increased, a lower external temperature was required to maintain stationary internal trailer conditions within the narrow temperature range (24 to 32°C) comprising the optimal thermoneutral zone for shipping pigs previously described (Lambooy 1988, 1991; Randal 1993; Randal & Patel 1994; Schrama *et al* 1996). External temperature, RH, and average speed travelled between observations all had a likely impact on the association between pig density and trailer temperature. At higher external temperatures, pigs increase heat dissipation, therefore heating and humidifying the interior of the trailer. The impact of pig density on in-transit losses can almost certainly be explained by the association between pig density and internal truck temperature. This would explain why pig density was not associated with in-transit loss after controlling for internal truck temperature. Hence, truck temperature is likely an explanatory antecedent variable in the causal pathway between pig density and in-transit loss (Dohoo *et al* 2003). At higher external temperatures, stocking densities must be reduced, because the pigs increase internal temperature conditions beyond their thermoneutral zone.

The significant random effect of the individual trip reflected differences between trips both within and between trailer types. The relatively high percentage of unexplained variation partitioned to this level suggests that factors other than those included as fixed effects were clustered by trip. These factors include specific conditions that vary between and within transport trips. Trip duration, time of day of trip, external air speed, presence of clouds or sun, and animal density are all associated with in-transit losses (Lambooy 1988; Schrama *et al* 1996; Warriss 1998a; Whiting & Brandt 2002). These factors may interact with trailer design, which was included in the current study as the random truck effect. Neither trucking company nor truck driver were associated with in-transit losses. This may be because there were no significant differences between the companies or the drivers. The owners of these companies volunteered to participate in the project. Although the owners were not drivers themselves, their drivers were aware of the fact that their trips were being monitored.

In-transit losses have significant animal welfare implications. Many pigs that die in-transit, die as a result of exposure to high temperatures and/or poor handling at loading and unloading. It is likely that many if not all pigs in the same group have experienced the same discomfort that lead to the death of one or more of the pigs. It is incumbent upon all industry stakeholders to do their part to reduce these losses.

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