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Causes of pre-slaughter mortality in Danish slaughter pigs with special emphasis on transport

P Barton Gade*†, L Christensen†, M Baltzer† and J Valentin Petersen‡

† Danish Meat Research Institute, Maglegaardsvej 2, DK-4000 Roskilde, Denmark
‡ Danish Bacon and Meat Council, Axelborg, Axeltorv 3 DK-1609 Copenhagen, Denmark
* Contact for correspondence and requests for reprints: pbg@danishmeat.dk

Abstract

Annual statistics for transport and lairage mortality were used to investigate factors leading to pre-slaughter mortality in Danish pigs. A subset of material from 2002, amounting to 17.8 million pigs, was used for a more detailed study of the effect of producer, haulier, abattoir and transport distance (< 100, 100–200 and > 200 km) on transport mortality. Total mortality was reduced eight-fold during the period that the halothane gene was being removed from the pig population, from 0.12% in the early 1980s to 0.016% in 2002. Overall, transport mortality increased with higher temperature and lower relative humidity/wind speed but a combination of temperature and humidity that fell into the danger zone, as defined by the Livestock Weather Safety Index, almost doubled transport mortality from a level of about 0.016 to 0.031%. Multiple deaths on the same transport were also more frequent during the hotter months of the year. Transport mortality increased with increasing transport distance, especially during warmer weather. Producers, hauliers and abattoirs had widely varying transport mortality. Eighty-nine percent of producers, 11% of hauliers and 86% of farmer transports had no mortality at all. Producers and farmer transports supplying less than 1,000 pigs had a higher transport mortality than those supplying more pigs, whereas it was independent of supply for hauliers. There were many confounding factors in this work, as producers, hauliers and abattoirs are linked and trends over the years can be affected not only by changes in the genetic make-up of the pig population but also by improvements in handling. Nevertheless, the study shows that internal environment within the vehicle and transport pattern, including the time the vehicle is stationary, are important factors for mortality and that particular efforts should be made if weather forecasts predict dangerous combinations of temperature and humidity. It is suggested that efforts to further reduce transport mortality in Danish pigs should concentrate especially on these factors and include a routine follow-up of all multiple deaths to pinpoint specific factors leading to mortality.

Keywords: *animal welfare, lairage, mortality, pigs, slaughter, transport*

Introduction

Transport and lairage mortality in pigs causes a significant economic loss in many countries and, in addition, the welfare of the animals dying, as well as those surviving, is compromised (Warriss 1998). More pigs die during transport than in the lairage and it is generally accepted that pigs dying in the lairage do so because of the effects of the previous transport (Cedervall 1966; Warriss 1998). The aetiology of transport and lairage mortality is complex and multifactorial. Two pole positions can be envisaged: the pig is susceptible to pre-slaughter handling conditions or the conditions during the period of moving the animal from its home pen to stunning at the abattoir are extremely stressful. In the first case, the pig may die even though pre-slaughter conditions and treatment is optimal; in the second they will only die if conditions and treatment are inappropriate.

Several factors have been found to affect pre-slaughter mortality and of these, a genetic condition caused by the halothane gene, is of major importance. Pigs that are homozygous for the gene have a biochemical defect in the sarcoplasmic reticulum of muscle tissue, which leads to leakage of Ca^{++} ions from muscle cells, metabolic acidosis and hyperthermia (Fujii *et al* 1991). Many studies have shown that mortality is closely related to the halothane gene and pigs that are homozygous for halothane have a much higher mortality than pigs resistant to halothane (Eikelenboom *et al* 1978, 1980; Barton Gade & Baltzer 1991; Christensen 1994). Moreover, McPhee *et al* (1994), Murray and Johnson (1998) and Fàbrega *et al* (2002) showed that mortality was not only higher in homozygous animals but also in carriers of the halothane gene. Fàbrega *et al* (2002) estimated that under Spanish environmental conditions, removal of the halothane gene from the pig population would lead to an eleven-fold decrease in pre-slaughter mortality (from 0.22 to 0.02%). They suggested that from the point of view of animal welfare, elimination of the halothane gene in existing breeding schemes would have a major beneficial effect.

Pigs cannot sweat and have difficulty in losing body heat, therefore physical exertion, stressful conditions and high environmental temperatures, especially in combination with high humidity, can lead to higher mortality during transport (Guise *et al* 1994; McPhee *et al* 1994; Warriss & Brown 1994; Abbott *et al* 1995). Thus, critical combinations of temperature and humidity are used in the US Livestock Weather Safety Index (Grandin 1992) to decide when transport is dangerous for pigs. Adequate ventilation in transport vehicles is one method of removing heat from the pigs being transported and several studies have indicated that optimising ventilation reduces transport mortality (Fabiansson *et al* 1979; Nielsen 1981; Christensen & Barton Gade 1999).

The aim of the present work was to use national transport and lairage mortality statistics for slaughter pigs, which have been collected annually by the Danish pig industry since 1975, to establish factors affecting mortality in Danish pigs that could be used as guidelines to further reduce transport and lairage mortality.

Materials and methods

Transport and lairage mortality

Figures from all co-operative abattoirs, covering 95% of the total pig slaughter, were used to show the trends in transport and lairage mortality for the period 1978 to 2002. During this period the total annual slaughter increased from 11,714,780 to 20,928,546 pigs. The registration of transport and lairage mortality was first standardised from 1992 so that any pig that is accepted with reservation by the abattoir, and that subsequently dies during the first 2 hours of holding in the sick bay, is considered to be a transport death; otherwise it is noted as a lairage death. The specific cause of death is not registered by the factories and hence is not known for the experimental material.

Then, pigs slaughtered at 17 of the co-operative abattoirs in 2002, 17,882,622 in all, were used for a more detailed investigation of factors affecting mortality. Each pig dying during transport was noted for producer number, haulier number, date and week of occurrence and for a subset of 16 abattoirs, transport distance: < 100 km, 100–200 km and > 200 km was known. The total number of pigs supplied by the producer and the total number of pigs transported by the haulier or farmer transporter was also noted. Hauliers can have more than one vehicle, but it was not possible to relate transport mortality to the individual vehicle in this work. Weather conditions were obtained for 2002 from the Danish Metrological Institute. Weather factors noted were average temperature, maximum and minimum average temperature, absolute minimum and maximum temperature, relative humidity in percent, average wind velocity in m s^{-1} and finally, number of hours of sunshine. These figures were used to establish possible factors leading to higher mortality with special emphasis on variation over the year and transport distance. Transport distance is confounded by stocking density in this work. In 2002, Denmark interpreted the EC Directive regarding stocking density during transport such that journeys over 4 hours use the recommended value of 0.42 m^2 per 100 kg pig, whereas those less than 4 hours use a stocking density of 0.35 m^2 per 100 kg pig. The rationale for this was that shorter journeys are over smaller, rougher roads and a tighter stocking density improves pig welfare under these conditions (Barton Gade 1998, 2000). Most journeys under 100 km will, therefore, be shorter than 4 hours and hence be carried out using a stocking density of 0.35 m^2 per 100 kg pig, whereas most journeys over 200 km will be longer than 4 hours and use a stocking density of 0.42 m^2 per 100 kg pig. The intermediate distance group will be a mixture of both stocking densities.

In an effort to find possible reasons for a higher mortality, a subset of 34 producers, who had a mortality of 0.100% or above and at least 4 dead pigs during the year, were investigated for effect of time of year and the occurrence of multiple transport deaths, and 75 hauliers with at least 10 pigs dying during transport during the year were investigated in more detail for effect of time of year, producer and the number of pigs dying during any one transport. The cut-off points used were arbitrarily chosen but ensured a high mortality that was not related to farm size for producers and that all hauliers with a numerically large number of dead pigs over the year, irrespective of numbers transported, were included. In these investigations, deaths are considered to take place mainly in the summer months if 60% or more of the pre-slaughter deaths from a producer or haulier occurred during the summer half year. Similarly, deaths were considered to take place mainly during the winter months if 60% or more of the pre-slaughter mortality took place in the winter half year. Otherwise deaths were considered to be independent of time of year. If two producers accounted for at least 30% of a haulier's deaths, then it was considered that the haulier's mortality was more or less producer dependent.

All results were investigated using a chi-squared test using SAS version 9.1 software package (2002–2003). For weather conditions, Pearson correlation coefficients were calculated between transport and lairage mortality and each weather factor separately and the best combinations of weather factors to describe transport and lairage mortality were investigated using R^2 analysis (SAS version 9.1 software package [2002–2003]).

Danish production conditions and transport pattern

As mortality levels will be affected by production conditions and the transport pattern valid in Denmark, it is relevant to describe the background on which the statistics are based. Danish pig production is based on the co-operative principle with producers being affiliated to certain companies and most producers use the same haulier and supply pigs to the same abattoir, although there are exceptions to these general rules, eg when the producer supplies more pigs on a given date than the usual haulier can cover or when transport to another abattoir is necessary to utilise abattoir capacity optimally. In the early 1980s there were no guidelines regarding fasting period but since January 1993 industry recommendations are for pigs to be fasted

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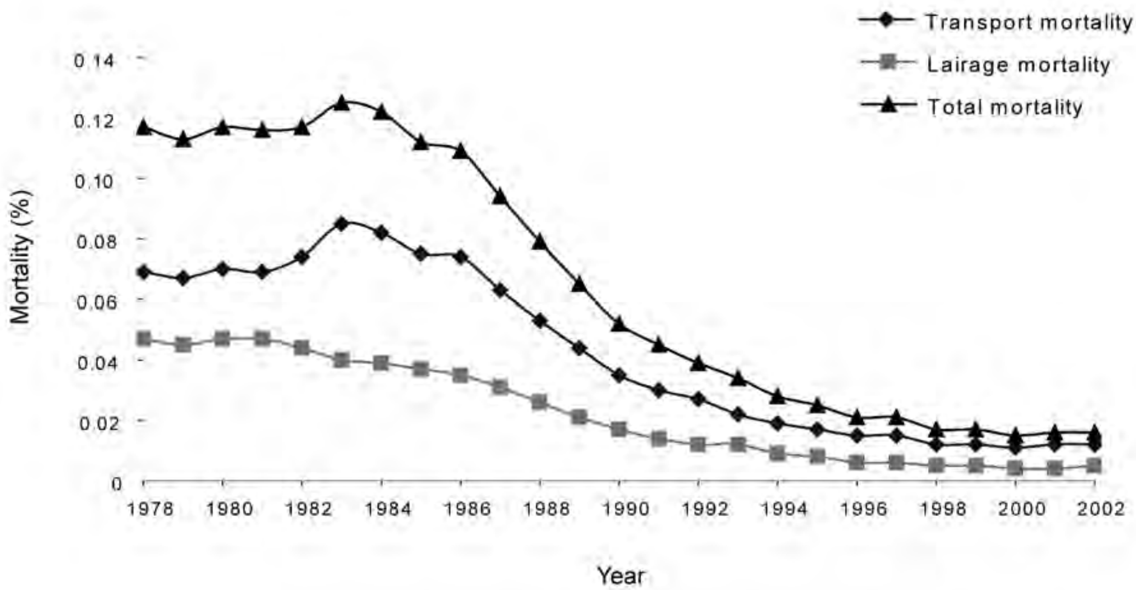
Figure 1



Transport, lairage and total mortality in Danish slaughter pigs during the period 1987 to 2002.

about 12 hours before collection from the farm to minimise faecal contamination during evisceration. To reduce the spread of production diseases, most Danish producers have delivery systems, where pigs are held away from the main herd for a shorter or longer time before collection. Loading takes place either using a ramp or more commonly using a tailgate lift to reduce physical exertion and eliminate the need for pigs to negotiate slopes. Electric goads may have been used by some hauliers in the 1980s but by 2000 these were no longer used at loading (or off-loading and further movement into lairage pens). Depending on the number of pigs to be delivered, a haulier may visit several producers to fill the vehicle but it is becoming increasingly common for producers to fill a whole vehicle at one time, thus eliminating stops during transport. Some producers transport their own pigs to the abattoir (farmer transports).

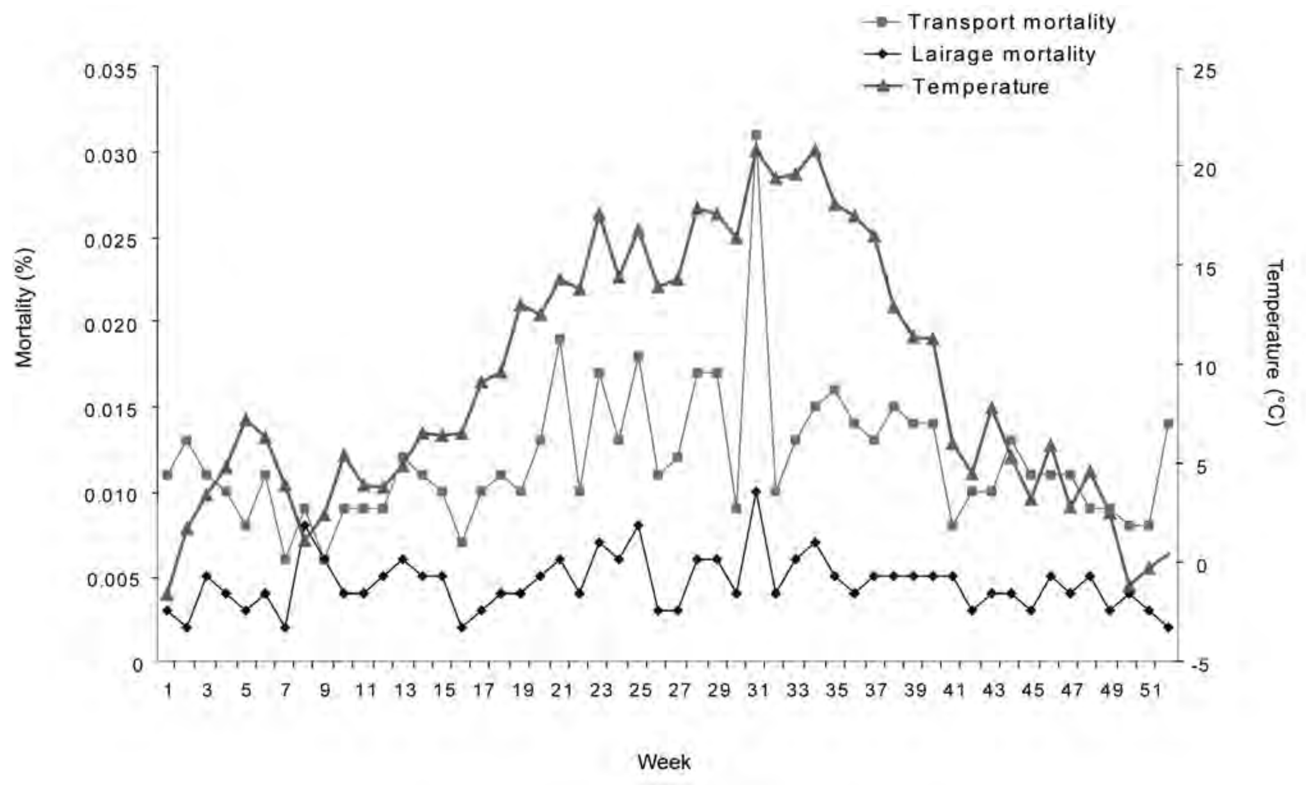
Major improvements to transport vehicles occurred from the middle of the 1990s with the increasing introduction of dedicated double-decker vehicles with forced ventilation. In 2002, it is estimated that 60% of transport vehicles were double-deckers, 35% single-deckers and 5% triple-deckers. Almost all multi-tiered vehicles have floating decks and forced ventilation systems with ventilation openings along the sides of the vehicle. Floating decks are of two types: decks moved using chains and fixed in position with bolts (about 70% of the total) and decks operated hydraulically (about 30% of the total). Some of the double-deckers and all of the triple-deckers are equipped with misting systems for cooling pigs in hot weather. All vehicles are divided into compartments of 15 to 30 pigs and all have a tail-gate lift to eliminate the need for slopes at loading. About 90% of vehicles have some form of rubber flooring, that is non-slip, insulating and reduces noise during loading and off-loading; otherwise flooring is profiled aluminium. All vehicles use sawdust as bedding, which is collected at the abattoir after vehicle cleaning. Farmer vehicles range from tractors and trailers to vehicles of a similar standard to those of hauliers.

In the experimental period most Danish slaughter pigs were 3 and 4 breed crosses of Landrace, large white, Duroc and Hampshire. Breeding stock is mainly supplied by the official Danish breeding system, so that, in contrast to the situation in many countries, pigs from breeding companies are only used to a minor extent. The breeding system began to eliminate the halothane gene in 1986 and in 2002 the pig herd was essentially free of the gene. Average warm slaughter weight has been increasing in recent years and was 78.1 kg for 2002. The average meat content in the carcass was 60.0% in 2002.

Supplementary investigations

To get some idea of the effect of vehicle design on transport mortality, the above material was supplemented with an investigation of vehicle design in hauliers chosen by an abattoir as having higher, similar and lower mortality figures compared to the national average for the period concerned (January–June 2003). The six vehicles chosen were inspected for design and usage by an experienced engineer. The investigation was descriptive only and no statistics were carried out.

Figure 2



Weekly transport and lairage mortality in relation to environmental temperature in 2002.

Table 1 Pearson correlation coefficients between transport and lairage mortality and weather conditions.

Weather parameter	Transport mortality	Lairage mortality	Total mortality
Average °C	0.61***	0.48***	0.60***
Minimum average °C	0.60***	0.45***	0.59***
Maximum average °C	0.61***	0.50***	0.61***
Minimum absolute °C	0.57***	0.43**	0.56***
Maximum absolute °C	0.61***	0.51***	0.61***
Hours of sunshine	0.46***	0.51***	0.50***
Relative humidity	–0.36**	–0.43**	–0.40**
Average wind speed (m s^{-1})	–0.39**	–0.14	–0.33**

*** $P < 0.001$, ** $P < 0.01$.

Results

Trends in total mortality

Transport, lairage and total mortality figures for the period 1978 to 2002 are shown in Figure 1. From 1978 to 1984, total mortality was essentially constant at about 0.12%. Thereafter, total mortality fell progressively until 1998 after which it remained essentially unchanged at just below 0.02%. Transport mortality showed an increasing trend until 1983, after which it decreased rapidly until 1998, and then it became more or less constant. Lairage mortality gradually decreased over the whole period. The actual figures for transport and lairage mortality in this figure should, however, be treated with caution, as the definition of what constitutes a transport death and what constitutes a lairage death was first completely standardised from 1992.

In 2002, average transport mortality was 0.012%, average lairage mortality 0.005%, giving a total average mortality of 0.016%. Even at this low level, there was a clear effect of time of year on mortality figures (Figure 2). Lairage mortality was relatively independent of time of year but transport mortality, and hence total mortality, increased during the summer months. In July and August transport mortality almost doubled compared to winter months. Higher correlations were found between temperature parameters and transport mortality than between temperature and

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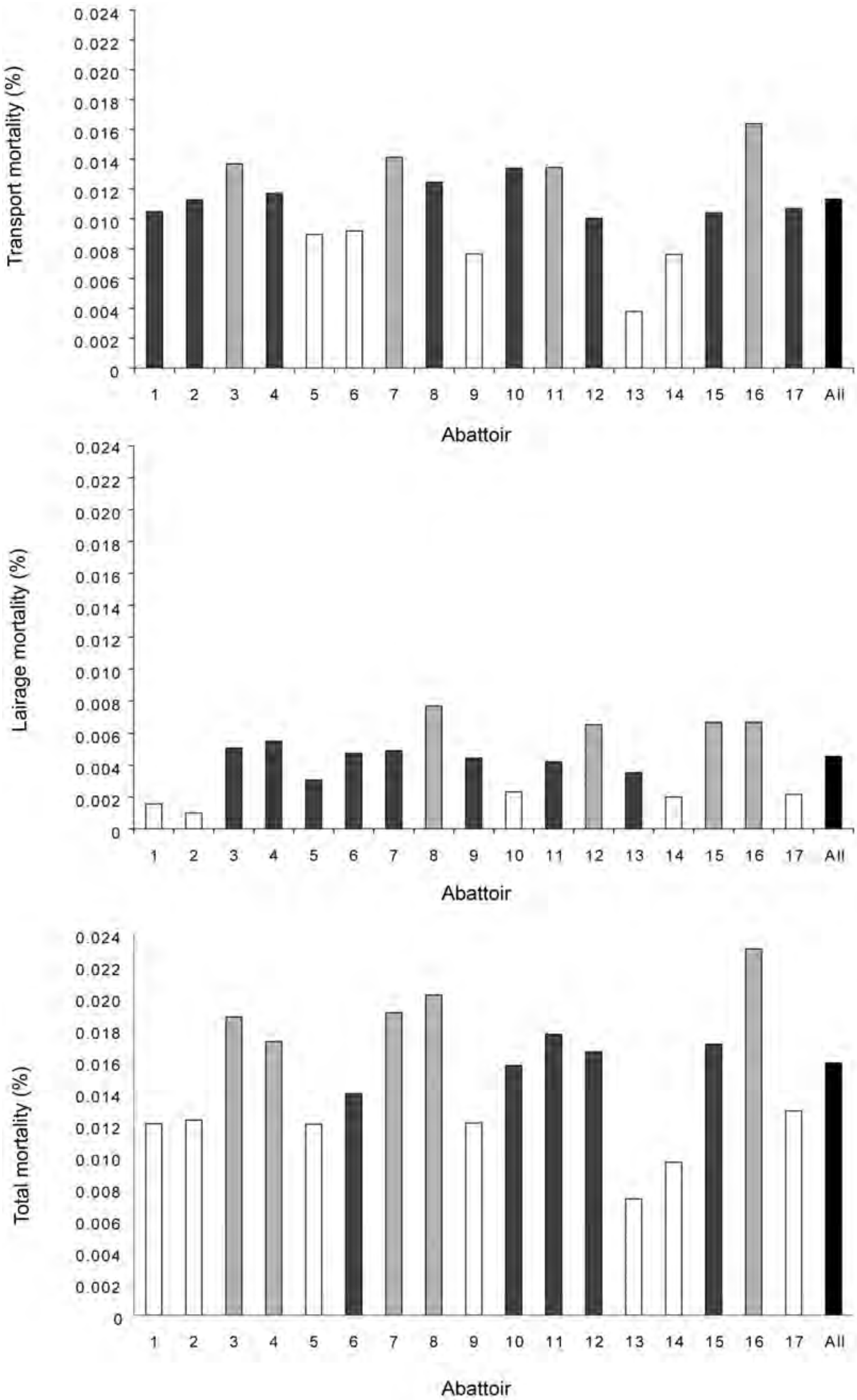
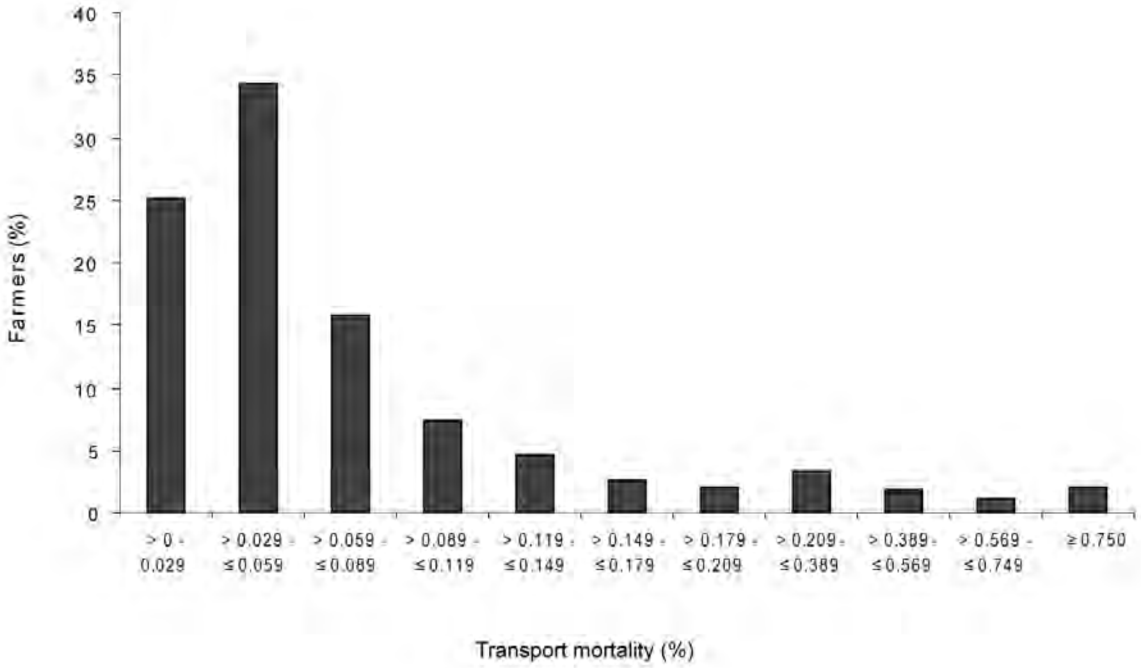
Figure 3



Transport, lairage and total mortality for abattoirs in relation to the country as a whole. White columns signify that an abattoir's mortality is significantly lower than the national average, light grey columns that it is significantly higher and dark grey that there is no difference.

Figure 4



Transport mortality distribution for farmers with at least one pig dying during transport.

lairage mortality (Table 1). Higher temperatures led to a higher mortality, and higher humidity and wind speed to a lower mortality. Three weather factors could explain 42% of the variation in transport mortality: maximum absolute temperature, relative humidity and wind speed. The best combination to describe lairage mortality was minimum and maximum average temperature and wind speed but this could only explain 29% of the variation.

Effect of abattoir

Pig supply to abattoirs varied from a minimum of 396,722 to 2,949,625 pigs per year. Transport mortality varied between 0.008 and 0.016%, lairage mortality between 0.001 and 0.008% and total mortality between 0.007 and 0.020% (Figure 3). There were significant differences between abattoirs for all mortality figures ($P < 0.0001$). A comparison of each abattoir with the national figures showed that factories 3, 7, 11 and 16 had a significantly higher transport mortality than the average and factories 5, 6, 9, 13 and 14 were lower than the average. For lairage mortality, factories 8, 12, 15 and 16 were higher than the average and factories 1, 2, 10, 14 and 17 were lower. Totally, factories 3, 4, 7, 8, and 16 were higher than the average and factories 1, 2, 5, 9, 13, 14 and 17 were lower.

Effect of producer

12,441 producers supplied pigs to the company's abattoirs in 2002, and of these, 89% had no transport mortality at all. Producers that did show transport mortality had, on average, 1.5 dead pigs and an average total supply of 3,414 pigs during the year. In this group, mortality was related to the size of farms and farms supplying less than 1,000 pigs had a significantly higher mortality ($P < 0.001$) than farms supplying 1,000 or more pigs (0.588% as against 0.029 to 0.086% for other groups). The distribution in transport mortality was not normal but skewed to higher values (Figure 4), corresponding to a median mortality for all producers of 0.050%.

Fifty-nine percent of producers with a mortality of 0.100% or above and at least 4 dead pigs during the year (variation 4–16) lost pigs either partly or wholly during the summer half year, 18% were independent of time of year and 23% lost pigs wholly or partly during the winter half year. Time of year affected the number of multiple deaths during any one transport. Thus, 80% of producers losing pigs mainly or wholly during the summer half year had at least one occurrence with two (and up to 7) dead pigs on the same transport. Week 31 accounted for 38% of the multiple deaths in this group. Fifty percent of producers losing pigs over the whole year had two or more dead pigs on the same transport with a maximum occurrence of three. Thirty-eight percent of producers losing pigs mainly or wholly during the winter half year had up to two dead pigs on the same transport.

As expected, pigs from most producers were transported by one haulier and slaughtered at one abattoir only (87% of the total). Eight percent were transported by one haulier but supplied to two abattoirs and 2% were transported by two hauliers to one abattoir. In the

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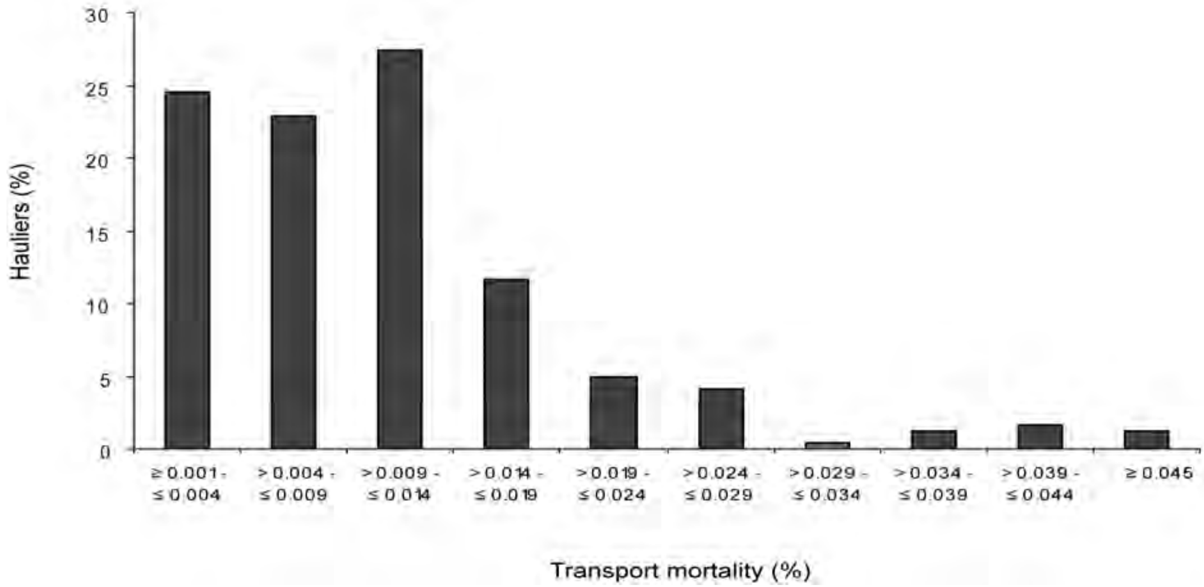
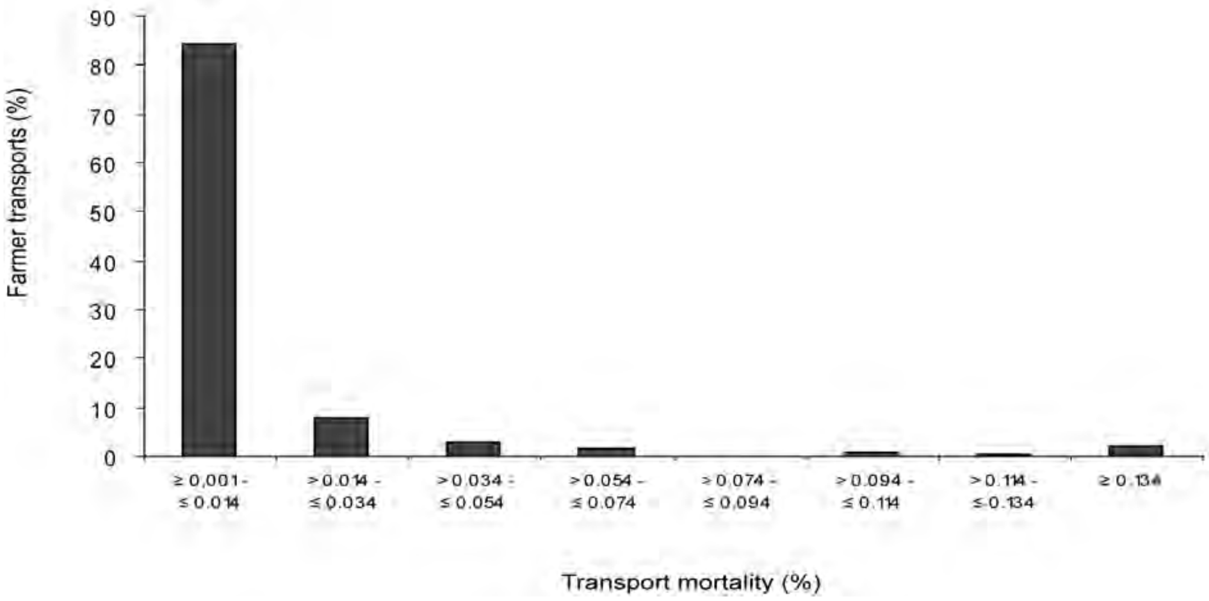
Figure 5



Transport mortality distribution for hauliers with at least one pig dying during transport.

Figure 6



Transport mortality distribution for farmer transports with at least one pig dying during transport.

latter case transports by two hauliers often occurred on the same day, presumably because there were too many pigs for the normal transport. The remaining producers showed various combinations of haulier and abattoir numbers, though never higher than three hauliers and three abattoirs.

Effect of haulier

In all, there were 241 hauliers and 275 farmer transports in 2002. Hauliers were responsible for the majority of pig transports (95%) and farmer transports only covered 5%. Consequently, the average number of pigs transported was much higher for hauliers than farmer transports (average numbers transported 77,933 and 3,736 respectively). The average numbers of pigs dying was 8.6 pigs for hauliers and 0.3 pigs for farmer transports. The distribution in transport mortality was skewed to higher values for both hauliers and farmer transports (Figures 5 and 6), corresponding to median values of 0.010 and 0% for hauliers and farmer transports, respectively. Mortality was not significantly different for

Table 2 Transport distance in relation to transport mortality for slaughter pigs in 2002.

Transport distance (km)	Total number of pigs	Percentage of pigs transported	Pigs dead on arrival	Transport mortality (%)
< 100	16,189,889	90.5	1,880	0.0116
100–200	1,441,793	8.1	243	0.0169
> 200	250,940	1.4	56	0.0223
Total	17,882,622	100.0	2,179	0.0122

Table 3 Details of vehicles with known mortality for the period January–June 2003.

Vehicle	Mortality (%)	Type	Ventilation	Outer colour	Flooring	Transport
1	0.022	Truck and trailer	N	D	Al	< 100 km
2	0.017	Truck and trailer	F from side (truck), F from front (trailer)	L	G	~ 100 km
3	0.011	Truck	F from front	L	G	–
4	0.011	Truck and trailer	F from front (truck), F from front (trailer)	D	G	~ 80 km
5	0.009	Truck	F from side	L	G	~ 100 km
6	0	Truck	F from side	L	G	~ 50 km

Ventilation: N = natural; F = forced. Outer colour: D = dark; L = light. Flooring: Al = profiled aluminium; G = rubber.

haulier and farmer transports, due to the high standard deviation of the latter, which was caused by mortality in transports with less than 10 pigs. Mortality was not affected by numbers transported for haulier transports but farmer transports of less than 1,000 pigs had a higher mortality than farmer transports above 1,000 pigs (0.408% as against 0.006 to 0.025% for other groups, $P < 0.001$). Haulier and farmer transports showed a significantly different pattern. Only 12% of hauliers were without transport mortality in 2002 compared to 86% of farmer transports ($P < 0.001$).

Thirty-six percent of hauliers with at least 10 pigs dying during transport during the year (variation 10 to 63 pigs) showed no effect of time of year and 52% showed a bias towards a higher mortality during the summer half year, in both cases more or less equally divided between those that were producer dependent and those that were not affected by producer. Twelve percent of hauliers showed a bias towards a higher mortality during the winter half year, and this was mainly producer dependent. Hauliers with higher numbers of pigs dying during transport had significantly more cases with multiple deaths per transport than hauliers with lower numbers of pigs dying during transport ($P < 0.001$).

Effect of transport distance

More than 90% of transports in 2002 were below 100 km and only 1.4% were over 200 km (Table 2). Transport mortality increased with transport distance and was significantly higher with longer transport ($P < 0.001$). 91–92 % of pigs transported for < 100 or 100–200 were restricted to one haulier only, whereas only 76% of pigs transported more than 200 km were restricted to one haulier.

There was only a tendency for transports over 200 km to have a higher transport mortality during the summer half year than transports of 100 and 100–200 km. However, the increase in transport mortality in week 31, which had the highest absolute temperature combined with a relatively high humidity, was much greater for transports over 200 km compared to the other transport distances and amounted to 10 times the values for weeks 30 and 32, 11% of the total mortality for that distance. The corresponding figures for 100 and 100–200 km were for a doubling of mortality relative to weeks 30 and 32 and respectively 6 and 4% of the total mortality.

Supplementary investigations

Some of the details of the vehicles selected for these supplementary investigations are shown in Table 3. In addition to these, all vehicles were equipped with a tail-gate lift and all were 2-tiered, both on the truck and trailer (if any). Vehicle 1 had an internal ramp of 3 m length on the truck but not the trailer, ie the truck had a fixed deck. All other vehicles and the trailer for vehicle 1 had floating decks. All vehicles were divided into compartments and in five, compartment walls were adjusted to ventilation openings, so that air flow within the vehicle was not obstructed. Vehicle 2, however, had solid partition gates between compartments, which compromised air flow.

The highest mortality (0.022%) was found in the vehicle without forced ventilation, an internal ramp (fixed deck), aluminium flooring and dark colouring of outer surfaces. The vehicle with the next highest mortality (0.017%) was of good standard but had compromised ventilation due to solid compartment walls within the truck and trailer. Both vehicles with 0.011% mortality were of good standard but had forced ventilation from the front and one was dark coloured on outer surfaces. Vehicles with the lowest mortality (0.009 and 0%) were both of a high standard with forced ventilation from the side. All transports were relatively short with maximum

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100 km and 3 hours duration. Mortality was not producer-related in vehicles 1, 3, 4 and 5 but for vehicle 2, 60% of the mortality originated from one transport from a single producer. This multiple death occurred at the beginning of June in a week where the weather turned hotter. The average temperature during this week was 17.8°C with a maximum of 26.3°C, an increase of 3.2 and 4.4°C compared to the previous week. Relative humidity increased during this period from 59 to 72% and average wind speed from 1.7 to 3.6 m s^{-1}. For the vehicle with no mortality at all (vehicle 6), only one producer was involved, whose holding area for collection was in complete accordance with industry guidelines (http://www.infosvin.dk). Among other factors for this producer, unfamiliar pigs were not mixed before loading.

Discussion

In a study such as this, there are many confounding factors. Trends over a number of years can be due both to genetic factors and to changes in transport vehicle design and transport pattern. Producers are mainly restricted to one haulier, who transports the pigs to one abattoir, so that it is difficult to state precisely which of the three parties in any given case is responsible for mortality or where, in the transport process, problems needing to be addressed are to be found. In addition, larger hauliers will have more than one vehicle and it was not possible to relate transport deaths to vehicle registration number in this work, although regarding deaths on the same day the identification number given to the dead pig can be used to ascertain whether deaths occurred on the same transport or not. However, despite these confounding factors, certain overall trends can be ascertained that can be useful to make general statements regarding transport and lairage mortality and what needs to be done to reduce overall mortality levels.

Firstly, efforts to remove the halothane gene from the commercial population seem to have had a significant effect on lowering transport and lairage mortality in Danish pigs. Christensen (1994) also showed that transport mortality was mainly affected by the halothane status of a pig population rather than transport conditions, as such. Total mortality has been reduced eight-fold from the 1980s until 2002 ie from 0.12 to 0.016%, which is less than the estimate of an eleven-fold decrease calculated by Fàbrega *et al* (2002) for eliminating the gene in Spanish pigs. Some of this decrease will, of course, have been due to improvements in vehicle design and handling. Overall mortality levels are now very low compared to other published figures (Allen *et al* 1974; Warriss 1995; Gispert *et al* 1996a; Murray & Johnson 1998; Fàbrega *et al* 2002; Kristoffersen 2004).

Secondly, transport (and to a lesser extent lairage) mortality is affected by weather conditions and is twice as high during the hotter months of the year compared to colder months. Many studies have shown that transport mortality is highest during the summer period (Cedervall 1966; Allen *et al* 1974; Fabiansson *et al* 1979; Warriss & Brown 1994, Riches *et al* 1996). Lendfers (1971) related mortality to environmental temperature and showed that transport mortality was more than twice as high at outside temperatures above 15°C than for temperatures below 10°C. Temperature was the main weather parameter affecting transport mortality in this study but relative humidity and wind speed also played a role. Higher temperature and lower relative humidity/wind speed led to increasing transport mortality. The relationships between transport mortality and temperature and wind speed were as expected. However, the relationship with relative humidity was not. Relative humidity was higher during the colder months of the year in 2002. It may well be that this is a general feature of the Danish climate, as the country is surrounded by water on three sides and prevailing winds often have to pass an expanse of water before reaching land. Week 31 had a much higher mortality than would be expected from temperature alone. However, this week was the only week in the year, where the combination of temperature and relative humidity passed the danger line in the US Livestock Weather Safety Index (Grandin 1992), indicating that weather conditions were particularly dangerous for pig transport. The effect of weather conditions during transport on lairage mortality will be ameliorated by conditions in the lairage itself, eg by using showering during hot weather to cool pigs, and the results also showed lower correlations between lairage mortality and weather factors.

For both producers and hauliers with a minimum of 4 and 10 dead pigs, respectively, during the year, there was a higher frequency of multiple deaths per transport during the summer half year. It is likely that one of the causes of higher transport mortality during hotter weather is related to environmental conditions within the vehicle, in particular to ventilation conditions. The supplementary investigation showed that the highest mortality occurred in a dark coloured vehicle without forced ventilation, as well as an internal ramp on the truck that will have increased the pigs' physical exertion when loading the upper tier. Reducing physical exertion in pigs has previously been found to reduce transport mortality in Belgian pigs with the halothane gene (Devloo *et al* 1971) and a survey carried out by Riches *et al* (1996) suggested that transport mortality was lower on floating deck than on fixed deck vehicles. Nielsen (1981) showed that a forced ventilation system halved transport mortality in Danish slaughter pigs. Fabiansson *et al* (1979) also pointed to improved ventilation in transport vehicles as a method of reducing transport mortality in Swedish slaughter pigs. In a study of commercial transports using a high standard double-decker vehicle with forced ventilation, Christensen and Barton Gade (1999) showed that transport mortality only occurred in the front lower compartment. Temperature was always higher in this compartment compared to other vehicle compartments, so that poorer ventilation was implicated. Riches *et al* 1996 also showed that deaths in transit were highest in the compartment immediately behind the cab compared to other compartments but in their work this was valid for both decks. Intermittent wetting of pigs during transport would be an effective method of lowering temperatures via evaporative cooling. Routine use of a misting system at temperatures above 20°C combined with forced ventilation led to a very low transport mortality in a Danish study (Christensen & Barton Gade 1999) and Guardia *et al* (1996) showed that misting during transport combined with other factors such as transport during the cooler parts of the day eliminated the seasonal effect on transport mortality in Spanish pigs. Research has shown that natural ventilation is adequate when the vehicle is in motion (Christensen & Barton Gade 1999; Chevillon *et al* 2002) but this may not be the case when the vehicle is stationary. Poorer ventilation need not occur at loading, if a forced ventilation system is used during the loading process (Kettlewell *et al* 2001).

Eighty-nine percent of Danish producers had no mortality at all in 2002, and of the 11% that had, the majority (88%) had only one or two dead pigs during the year. However, some producers did have a higher mortality and this was sometimes associated with multiple deaths on a single transport, presumably because of some incident during collection or transport. For the sub-group showing mortality, producers supplying less than 1,000 pigs during the year had significantly higher transport mortality than producers supplying more pigs. It cannot be discounted that some smaller farmers may not incorporate breeding goals to the same extent as larger producers do, so that they may still have some pigs with the halothane gene in the herd. A more plausible explanation, however, could be that the transport pattern is different. With relatively few pigs per delivery it is likely that there will be several stops on the way to the abattoir, where environmental conditions within the vehicle may be compromised in warmer weather. Many larger producers will be able to fill a vehicle, so that there will be no stops on the way to the abattoir. However, the finding that smaller producers have a higher mortality than larger producers may simply be an artefact. Most of the smaller producers had only one dead pig and transport mortality will automatically increase as the number of pigs supplied becomes smaller.

Hauliers accounted for 95% of total transports and 88% of them had some transport mortality during the year. Transport mortality was not affected by the number of pigs a haulier transported but there was a producer effect, especially during the colder months of the year. For some hauliers a major part of their transport mortality was due to pigs from certain producers. Hauliers with higher numbers of pigs dying during transport also tended to have a greater frequency of multiple deaths on the same transport during the summer months, which would indicate that their vehicles were less adequate in fulfilling pigs' needs during transport in hotter conditions compared to hauliers with lower numbers of pigs dying during transport. Farmer transports were responsible for 5% of the total transport and only 14% of these showed transport mortality in 2002. Seventy-two percent of these lost only one or two pigs during the year. Farmer transports overall had a similar transport mortality to haulier transports, but this was due mainly to a few very small farmer transports with dead pigs. Farmer transports of less than 1,000 pigs per year also had higher transport mortality than transports of 1,000 pigs or more. Farmer transports will generally be shorter transports direct to the abattoir but it is likely that the vehicles used for transports of less than 1,000 pigs annually are of poorer standard than those used for transports of 1000 pigs or more. Again, however, this finding may be an artefact, as with producers generally.

If all producers with a mortality of minimum 0.100% or above and at least 4 dead pigs during the year had had a mortality of zero, then the total average transport mortality for 2002 would have been reduced only slightly, from 0.012 to 0.011%. However, if all hauliers with minimum 10 pigs dying during transport during the year were reduced to maximum 10 pigs, then the total transport mortality for 2002 would have been reduced from 0.012 to 0.007%. Clearly, efforts to reduce haulier mortality rather than producer mortality will be a more effective strategy.

Previously, it was thought that transport mortality was not related to transport distance, as removal of a pig with the halothane gene from its familiar environment, loading it onto a vehicle and mixing it with unfamiliar animals was sufficient to trigger the mechanism leading to hyperthermia and death. However, this study and recent Swedish work using 960,000 pigs from one abattoir (Kristoffersen 2004) show that transport mortality does increase with increasing transport distance, in the latter case from 0.015% for transports of less than 100 km to 0.089% for distances above 200 km. As in the present Danish pig population, the Swedish population is essentially free of the halothane gene and it seems that under these conditions transport mortality is affected by transport distance, ie some factor in the transport has a cumulative effect, which ultimately leads to death in certain individuals. A plausible explanation could be that mortality will increase with time if the internal environment in the vehicle is less than optimal, as pigs would be subjected to sub-optimal conditions for a longer period during longer transports. In addition, loading time may take longer in longer transports, as these will tend to be larger transports. Kristoffersen (2004) also noted that longer transports involved a higher number of pigs per transport and that a longer loading time contributed to the higher transport mortality in his study. The higher mortality during the hottest week of the year for transports over 200 km would support this explanation, as sub-optimal conditions within the vehicle would have had a greater effect in warmer weather.

It is logical to assume that a higher stocking density will increase the heat load on a vehicle and hence lead to higher transport mortality, if heat removal from the vehicle is inadequate. However, stocking density does not seem to have been important in this study, as space allowance per pig was higher with transports above 200 km than in transports below 100 km. This means that either the stocking density in the range used in Denmark (0.35 and 0.42 m^2 per 100 kg pig) is not important for mortality or that 0.42 m^2 per 100 kg pig is not sufficient to lower mortality in the vehicles used in 2002. A survey of seven European countries carried out in connection with an EU transport project also showed that there was little relationship between transport mortality and average stocking densities, which were mainly in the range 0.35 and 0.39 m^2 per 100 kg pig, even when differences in halothane susceptibility of the pig populations were taken into account (Christensen 1994). Gispert *et al* (1996b) showed that increasing stocking density to more than 0.40 m^2 did not affect transport mortality at four of five Spanish abattoirs studied, compared to stocking densities below 0.40 m^2. At the fifth abattoir transport mortality was reduced by giving pigs more space. Riches *et al* (1996) noted that more transport deaths occurred in lorry compartments stocked at higher than the average lorry density but this was less marked in summer in their work. In an experiment using 232,000 pigs and 4,547 journeys, Lendfers (1971) found that an allowance of 1.2 pigs m^{-2} gave a lower mortality than other space allowances used. However, only 0.23% of all transports used this density and no live weight was given in this work, so that actual stocking densities are not known. Moreover, transport at this low density had significantly fewer pigs per transport than the other densities, so that there may have been confounding factors with transport pattern and vehicle in this work.

Animal welfare implications

Based on the results of this study, efforts to further reduce transport mortality in Danish pigs should concentrate particularly on the haulier sector, as most hauliers had mortality whereas most producers and farmer transports did not. Areas of focus should be elimination of the increase in mortality in warmer weather and a reduction of the occurrence of multiple deaths in single transports. Particular efforts should be made if weather forecasts show combinations of temperature and humidity that will be dangerous for pig transport. Thus, any treatment of pigs in the collection area, if this is used, should emphasise keeping pigs cool and reducing physical exertion at loading. The ventilation standards of transport vehicles must be improved to ensure adequate air flow throughout the vehicle, especially when it is stationary. This means that vehicles must use the forced ventilation system during the loading process at higher temperatures, eg at 20°C or above. Misting of pigs at higher temperatures is also a possibility. Industry recommendations in Denmark are for misting to take place intermittently during transport when environmental temperatures reach 25°C. Over and above these general recommendations, a routine follow-up of all multiple deaths on the same transport should be carried out and a catalogue of factors leading to increased transport mortality made that can be used to avoid such situations in the future. Abbott *et al* (1995) also emphasised the importance of routine follow-up as an aid to reducing transport mortality.

Conclusions

After removal of the halothane gene from a pig population, the main factors affecting transport mortality are environmental temperature, the design and use of transport vehicles and the distance transported to the abattoir. An inadequate internal environment will subject pigs to suboptimal conditions during transport and this will be exacerbated during warmer weather and over longer transports. All new vehicles should be equipped with forced ventilation and a misting system to ensure the best possible internal environment during transport and these systems should also be used whenever the vehicle is stationary.

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