TRAVEL SICKNESS AND MEAT QUALITY IN PIGS

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Abstract *Animal Welfare 1999, **8:** 3-14*

An experiment was conducted to investigate the incidence of travel sickness in pigs, specific hormone concentrations at exsanguination and subsequent meat quality. Fifty, 80kg slaughter pigs were transported on a lorry for 4.5h. During the journey, behavioural observations of the individually marked pigs were made by scanning every 8min to establish whether the pigs exhibited certain symptoms of travel sickness (foaming at the mouth and chomping) and incidences of retching and vomiting were noted as they occurred. Upon arrival at the slaughterhouse, pigs were unloaded, slaughtered immediately and a blood sample was taken at exsanguination for analysis of plasma cortisol, beta-endorphin and lysine vasopressin concentrations. On the day following slaughter, the chilled carcase of each pig was assessed for meat quality (using pH, Fibre Optic Probe, and Tecpro Pork Quality Meter measurements) in the longissimus dorsi, semimembranosus *and* adductor *muscles to determine the incidence of PSE (pale, soft, exudative) or DFD (dark, firm, dry) meat quality. Twenty-six per cent of the pigs (a total of 13 individuals) vomited or retched during the journey. There was no relationship between the incidence of travel sickness and either the concentrations of the hormones analysed at exsanguination or subsequent meat quality. Correlations revealed no significant relationship between concentrations of the hormones and meat quality measurements.*

Keywords: *animal welfare, lysine vasopressin, meat quality, pigs, stress hormones, travel sickness*

Introduction

There has been considerable interest in the welfare of pigs during transport (eg Guise & Penny 1989a; Lambooy & Engel 1991; Dalin *et al* 1993; Randall 1993; Geers *et al* 1994; Bradshaw *et al* 1996a, b) and it has recently been established that under certain conditions pigs may become travel sick (Bradshaw *et al* 1996a, b). The degree to which travel sickness is a problem in normal commercial practice remains unclear (Bradshaw & Hall 1996; Riches *et al* 1996). Bradshaw *et al* (1996a), travelling with pigs in the main body of the vehicle, found that nausea in some individuals was detected by the sound of retching rather than immediate direct observation (Bradshaw & Hall 1996). In addition, many pigs are not fed before transport and may vomit fluid (or merely retch), while analysis of video tapes may underestimate the number of travel sick individuals because some pigs are obscured by others. Therefore, direct observation of pigs during transport appears to be essential in order to allow accurate identification of all travel sick individuals (Bradshaw & Hall 1996).

Bradshaw *et al* (1996a, b) conducted experiments on commercial livestock lorries in order to investigate the incidence of travel sickness when pigs were mixed or when they travelled on a long (8h) journey. The onset of travel sickness appeared to be delayed by fighting when unfamiliar pigs were mixed during the journey (Bradshaw *et al* 1996a) and a number of specific symptoms of travel sickness were identified during the journey (sniffing, foaming, chomping, retching and vomiting) which appeared to occur sequentially (previously reported in Bradshaw *et al* 1995). In addition, Bradshaw *et al* (1996b) showed that concentrations of plasma lysine vasopressin (LVP) appeared to be elevated during a period of travel sickness noted during the course of an 8h journey. This supported the results of previous work conducted on pigs where Forsling *et al* (1984) found that exposure to vibration and noise led to vomiting and raised concentrations of plasma LVP.

Considerable research has been conducted to assess meat quality in relation to pre-slaughter transport and handling (eg Warriss & Brown 1985; Guise & Penny 1989a, b; Warriss *et al* 1994; 1995). These studies have included investigations of new methods of assessment of meat quality (eg Warriss *et al* 1989a; 1994), effects of method of loading and temperature (eg Nanni-Costa *et al* 1996), effects of tier level during the journey (eg Barton-Gade *et al* 1996a) and transport conditions (eg Schütte *et al* 1996). Many of these studies have also sought to relate stress hormone levels at exsanguination to meat quality (eg Warriss *et al* 1994; Barton-Gade *et al* 1996a). Some studies have now been conducted which involve direct behavioural observation of the pigs during the road journeys (eg Bradshaw *et al* 1996a, b) and assessment of the carcases after the journey is complete (eg Warriss & Brown 1985; Guise & Penny 1989a, b). However, there have not been any studies which have sought to relate these direct behavioural observations in transit to hormone levels at exsanguination and subsequent meat quality.

In the present study we wished to establish: (i) the incidence of travel sickness during a 4.5h journey in groups of slaughter-weight pigs; (ii) whether concentrations of hormones (cortisol, beta-endorphin and LVP) at exsanguination provide an indication of which pigs had been the most travel sick during the journey (which would allow further study of travel sickness without having to make direct behavioural observations during the journey); (iii) whether those pigs which become travel sick have particularly poor meat quality (which would provide impetus for research into the design of lorries without the vibration characteristics likely to cause travel sickness); and (iv) whether there was any relationship between concentrations of stress hormones at exsanguination and meat quality measurements.

Materials and methods

Vehicle and subjects

A 17t commercial livestock lorry (4-wheel rigid chassis) was hired (as described in Randall & Bradshaw 1998). Fifty, 80kg slaughter pigs (26 male, 24 female) were transported for 4.5h (25 each day for 2 days, with food but not water withdrawn the previous evening at 1700h). On each of the 2 days the pigs were loaded at 0800h and transported in two groups of 13 (front pen) and 12 (rear pen) at an average speed of 49km h^{-1} and a stocking density of 0.49m^2 pig^{-1}. This stocking density was lower than normal commercial practice due to constraints imposed by vehicle design. Each group consisted of pigs which had been housed together before transport.

Procedure

On day 1, pigs were loaded onto the lorry from a raised loading bay at 0800h. Thirteen pigs were placed in a pen in the front of the vehicle and 12 pigs were placed in the rear of the vehicle. The procedure followed on day 2 was identical to that on day 1. The experimenter travelled in the middle pen on the vehicle between the two groups in order to allow direct observation of behaviour. The presence of the researcher had very little effect on the behaviour and physiology of the pigs due to the general and greater disruptive effect of their transportation. Pigs were marked individually with a number on their backs and slap marked according to normal commercial practice before loading. This allowed the behaviours and corresponding meat quality characteristics of individual pigs to be identified. Pigs were scanned every 8min for certain symptoms of travel sickness (sniffing, foaming at the mouth and/or chomping). Incidences of retching and vomiting were noted as they occurred.

On each day, upon arrival at the slaughterhouse, pigs were unloaded by means of a raised tailgate and driven through lairage. No time was spent in lairage so that hormone concentrations at exsanguination could not reflect a response to a period of rest subsequent to transport. Pigs were driven two at a time into a lift which descended into mixture of carbon dioxide (CO_2) and ordinary air. Following 100s in the gas mixture (79% CO_2 at point of entry rising to 90% at the base of the shaft), which stunned the pigs, they were slaughtered immediately and a blood sample was collected from each pig at the point of exsanguination in a 9ml heparinized sample tube (Monovette, Sarstedt Ltd, Beaumont Leys, UK). The blood was centrifuged immediately and the resultant plasma divided into 1ml aliquots. These were frozen in dry ice and subsequently stored at -30°C pending radio-immunoassay for cortisol, beta-endorphin and LVP. Plasma cortisol was assayed as described in Parrott and Goode (1992). Beta-endorphin was assayed as described by Fordham *et al* (1989) using porcine beta-endorphin (Bachem, Pennsylvania, USA) as iodinated tracer and standards. The antiserum was supplied by Dr G Lincoln (Edinburgh). The radio-immunoassay for LVP was conducted as described in Thornton *et al* (1987).

On the day following slaughter, the chilled carcases of the pigs were assessed for meat quality. Triplicate readings of ultimate pH (pHu = pH measured 24h after death) were made in the *m. longissimus dorsi* (LD), *m. semimembranosus* (SM) and *m. adductor* (AD). Triplicate light-scattering readings were made in the LD and SM using a fibre optic probe technique (FOP – MacDougall 1984), and measurements of conductivity were made in the LD using a Tecpro Pork Quality Meter (PQM – Tecpro GmbH, Munich, Germany). The use of the FOP has been validated by Warriss *et al* (1989), and the use of the PQM by Warriss *et al* (1991). The mean values of the three readings were used in the analysis of data. Evaluation of meat quality as either PSE (pale, soft, exudative) or DFD (dark, firm, dry) was then conducted according to recently standardized methods (Barton-Gade *et al* 1996b).

Thus, an ultimate pH (pHu) in the LD and SM exceeding 5.90 was categorized as DFD (a pHu of 5.90–6.09 was classed as slightly DFD, and one in excess of 6.10 as DFD). Warriss *et al* (1989b) found that the relationship between the pHu in the AD and the LD may be represented by the equation:

$$pHu\ AD = 0.089 + 1.02\ pHu\ LD$$

Thus, a pHu of 5.90 in the LD (Barton-Gade *et al* 1996b) gives a corresponding value of 6.1 in the AD. Any carcases with a pHu in the AD which exceeded 6.1 were therefore classified as DFD (those with a pHu of 6.10–6.29 were classed as slightly DFD, and those with a pHu exceeding 6.30 were classed as DFD). In order to categorize carcases for incidence of PSE the following categories were used: FOP values in the LD and SM in excess of 40 were classified as PSE (40–50 was slightly PSE), and a PQM value in excess of 5 (with values of 5–6 classed as slightly PSE) (Barton - Gade *et al* 1996b). A carcase was classified as DFD or PSE if it showed symptoms of poor meat quality (including slight symptoms) in one or more muscles.

The motion of the vehicle during the journey was characterized by means of accelerometer equipment, details of which have been previously reported (see Randall & Bradshaw 1998).

Data analysis

First, the number of pigs exhibiting specific symptoms of travel sickness (ie foaming, chomping, retching and/or vomiting) was calculated.

Second, analyses were conducted in order to investigate whether concentrations of plasma cortisol, beta-endorphin and LVP at exsanguination provided an indication of which pigs had been the most travel sick during the journey. This consisted of two main analyses: (i) individual pigs were classified as travel sick if they had either retched or vomited; then a high hormone category was also established according to whether their individual concentrations of a particular plasma hormone at exsanguination (cortisol, beta-endorphin and LVP) lay in the upper quartile range (inclusive). This procedure was then repeated except, having classified individual pigs according to whether they retched or vomited, a low hormone category was established based on whether their individual hormone concentrations lay in the lower quartile range (inclusive). Each high/low hormone group therefore consisted of 13 individuals, which also corresponded to the number of travel sick pigs (ie pigs that retched or vomited). A chi-square test was conducted to establish whether travel sick pigs had either particularly high or low concentrations of hormones. (ii) Individual pigs were classified as travel sick if they exhibited any combination of the more advanced symptoms of travel sickness (ie foaming, chomping, vomiting and/or retching) and then also according to whether their concentrations of a particular plasma hormone (cortisol, beta-endorphin and LVP) at exsanguination were higher or lower than the median value for all 50 pigs in the group. Each high/low hormone group therefore consisted of 25 individuals, although a total of 32 individuals exhibited symptoms of travel sickness (foaming, chomping, vomiting and/or retching). Travel sick individuals were related to individuals belonging to the high/low hormone groups using a chi-square analysis.

Third, an analysis was conducted to investigate whether those carcases which exhibited PSE or DFD meat quality came from individuals which had been travel sick during the journey. Again this consisted of two analyses: (i) individual pigs were classified as travel sick if they had retched or vomited, and also according to whether they exhibited poor meat

quality (PSE or DFD). Approximately equal numbers were travel sick (n = 13) as were PSE or DFD (n = 12 and n = 17 respectively). (ii) Pigs were then additionally classified as travel sick if they exhibited any combination of the more advanced symptoms of travel sickness (foaming, chomping, vomiting and/or retching) and according to whether they exhibited poor meat quality (PSE or DFD). Travel sick individuals for each analysis were then related to individuals exhibiting poor meat quality (PSE or DFD) using a chi-square analysis.

Finally, the mean (± SEM) concentrations of plasma cortisol, beta-endorphin and LVP were calculated, and simple correlation analyses conducted in order to establish whether the concentrations of these plasma hormones were related to the specific measurements of meat quality (pHu in the LD, SM and AD; FOP in the LD and SM; PQM in the LD).

Results

Thirteen pigs (26% of the animals) vomited or retched during the journeys (see Table 1), and these were distributed approximately equally over the 2 days (seven pigs on day 1, six on day 2). A total of 26 pigs (52%) foamed or chomped, while 32 pigs (64%) exhibited any combination of the symptoms retch, vomit, foam and/or chomp. Six of the pigs retched or vomited but did not foam or chomp.

Table 1 **Number and percentage of pigs (n = 50) exhibiting symptoms of travel sickness (sniffing, foaming and retching and/or vomiting).**

	Behaviour			
	Sniff	**Foam/chomp**	**Foam/chomp/ retch/vomit**	**Retch/vomit**
Number	49	26	32	13
Per cent	98	52	64	26

The number of individual pigs classified as exhibiting particular symptoms of travel sickness and specific high/low hormone concentrations are shown in Tables 2a and 2b. In Table 2a, a total of 13 pigs were classified as belonging to each of the high/low hormone (cortisol, beta-endorphin and LVP) groups allocated according to the upper/lower quartile value (inclusive) and 13 individuals were classified as travel sick (retched or vomited). Few individuals showed symptoms of both travel sickness and high/low hormone concentrations (eg for cortisol: three for high and six for low; for beta-endorphin: two for high and six for low; and for LVP: four for high and three for low). Table 2b shows that a total of 25 pigs were classified as belonging to each of the high/low hormone groups (ie with concentrations classified as higher or lower than the median for the whole group) and 32 individuals were classified as travel sick (foaming, chomping, retching and/or vomiting). There was no significant relationship between the incidence of travel sickness and high/low hormone concentrations.

In the analyses presented in Tables 2a and 2b, no significant relationships were found between the incidence of travel sickness and high or low concentrations of hormones at exsanguination ($P > 0.05$ in all cases). Thus concentrations of cortisol, beta-endorphin and LVP at exsanguination did not provide any indication of which pigs had been the most travel sick during the journey.

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Table 2a **Contingency tables showing: (i) the number of individuals travel sick (defined as individuals which retched and vomited) or not travel sick vs the number of pigs exhibiting high concentrations of the specified hormones (ie with concentrations in the upper quartile range; n=13) or not showing high concentrations of these hormones (n = 37); (ii) the number of individuals travel sick (defined as above) or not travel sick vs the number of pigs exhibiting low concentrations of the specified hormones (ie with concentrations in the lower quartile range; n = 13) or not showing low concentrations of hormone (n = 37).**

Hormone	High or low concentrations of hormone (upper/ lower quartile)	Number of pigs travel sick	Number of pigs not travel sick	Row total	Chi-square	*P* value
(i) Cortisol	High	3	10	13		
	Not high	10	27	37	0.07	>0.50
Column totals		13	37	50		
(ii) Cortisol	Low	6	7	13		
	Not low	7	30	37	3.70	>0.05
Column totals		13	37	50		
(i)Beta-endorphin	High	2	11	13		
	Not high	11	26	37	1.02	>0.10
Column totals		13	37	50		
(ii)Beta-endorphin	Low	6	7	13		
	Not low	7	30	37	3.70	>0.05
Column totals		13	37	50		
(i) LVP	High	4	9	13		
	Not high	9	28	37	0.21	>0.50
Column totals		13	37	50		
(ii) LVP	Low	3	10	13		
	Not low	10	27	37	0.07	>0.50
Column totals		13	37	50		

The total number of pigs showing PSE or DFD characteristics for each measurement in each muscle is shown in Table 3. Seventeen pigs were classified as PSE (of which nine were slightly PSE); all these were classified according to PQM values in the LD (and none by FOP in LD and SM). A total of 12 pigs showed DFD in one or more muscle (LD, SM or AD), with four showing DFD in more than one muscle. A total of 25 individual carcases showed PSE or DFD in one or more muscle, and four of these showed signs of both.

Table 4 shows the number of travel sick individuals exhibiting symptoms of poor meat quality (PSE or DFD). Those pigs which were travel sick (defined as those individuals which exhibited retching or vomiting or those individuals which exhibited any combination of foaming, chomping, retching and/or vomiting) did not have poor meat quality (PSE or DFD) ($P > 0.05$ in all cases).

Table 2b **Contingency tables showing the number of individuals travel sick (defined by the symptoms foaming, chomping, retching and/or vomiting) or not travel sick vs those individuals exhibiting high or low hormone (cortisol, beta-endorphin and LVP) concentrations (defined as values greater or lesser than the median, n = 25).**

Hormone	High or low concentrations of hormone (upper/ lower quartile)	Number of pigs travel sick	Number of pigs not travel sick	Row total	Chi-square	*P* value
Cortisol	High	16	9	25		
	Low	16	9	25	0.00	>0.90
Column totals		32	18	50		
Beta-endorphin	High	16	9	25		
	Low	16	9	25	0.00	>0.90
Column totals		32	18	50		
LVP	High	14	11	25		
	Low	18	7	25	1.39	>0.10
Column totals		32	18	50		

Table 5 shows the correlation coefficients between meat quality measurements (pHu in the LD, SM and AD; FOP in the LD and SM; PQM in the AD) and concentrations of plasma cortisol, beta-endorphin and LVP at exsanguination. There were no significant correlations between meat quality and plasma hormone (cortisol, beta-endorphin and LVP) concentrations at exsanguination ($P > 0.05$ in all cases). The mean (± SEM) concentrations of the hormones were as follows: cortisol, 114.00 ± 5.27 nmol l^{-1}; beta-endorphin, 152.27 ± 8.63 pmol l^{-1}; LVP, 2.76 ± 0.3 pmol l^{-1}

Table 3 **Number and percentage of pigs showing DFD and PSE meat characteristics for each of the measures (pHu, FOP and PQM), calculated according to Barton-Gade *et al* (1996b). See text for abbreviations.**

pHu LD	pHu SM	pHu AD	FOP LD	FOP SM	PQM LD
3 DFD	10 DFD	3 DFD	0	0	17 PSE
6%	20%	6%	0	0	34%

Discussion

This is the first study which has involved the direct observation of substantial groups of slaughter-weight pigs during transport in order to record symptoms of travel sickness. The only previously comparable study involved 12 groups of four pigs (half of which were mixed and half unmixed) transported on a 1.5h journey (Bradshaw *et al* 1996a). In the unmixed condition, 33 per cent of the pigs (8 out of 24) retched or vomited, while in the mixed condition, the pigs showed no obvious evidence of travel sickness. It was concluded

Table 4 **Number of individuals (n = 50) showing symptoms of travel sickness (classified according to whether they retched and vomited [n = 13], and any combinations of foaming, chomping, retching and/or vomiting [n = 32]) and symptoms of poor meat quality (PSE or DFD meat).**

Travel sickness symptoms	Meat quality (PSE or DFD)	No pigs showing travel sickness symptoms	No pigs with travel sickness symptoms and PSE/DFD	Chi-square	*P* value
Retch/vomit	PSE	13	5	0.16	>0.5
Retch/vomit/ foam/chomp	PSE	32	12	0.48	>0.1
Retch/vomit	DFD	13	2	0.71	>0.1
Retch/vomit/ foam/chomp	DFD	32	5	3.41	>0.05

that, in the mixed condition, the direct effect of the journey appeared to be delayed due to fighting (which was absent in the unmixed condition). Since the journey lasted only 1.5h it was further suggested that the mixed pigs might suffer the effects of the journey (and become travel sick) once aggressive behaviour ceased some time after the end of the study period (Bradshaw *et al* 1996a).

Table 5 **Correlation coefficients (*r*) between meat quality measurements (pHu in the LD, SM and AD, FOP in the LD and SM; PQM in the AD) and concentrations of plasma cortisol, beta-endorphin and LVP at exsanguination. See text for abbreviations.**

Hormone	pHu LD	pHu SM	pHu AD	FOP LD	FOP SM	PQM LD
Cortisol	0.176	0.048	0.065	0.114	0.050	0.242
Beta-endorphin	0.031	0.128	0.017	0.067	0.125	0.093
LVP	0.126	0.208	0.117	0.016	0.114	0.028

No coefficients were significant, $P > 0.05$ ($r = 0.273$, $P = 0.05$).

In the present study, over a quarter of the pigs retched or vomited and over 50 per cent exhibited the advanced symptoms of travel sickness (ie foaming at the mouth and chomping). The symptoms of travel sickness in pigs have been previously reported and discussed (see Randall & Bradshaw 1998). Suffice it to say, the symptoms appear to occur sequentially with only some of the pigs progressing through all the stages to the point of vomiting. The travel sickness symptom which should be addressed with the most caution is sniffing (which was not included in the present analysis), and this has been discussed elsewhere (Randall & Bradshaw 1998). While foaming may occur in some other contexts (eg in sows during approach tests when introduced to a novel environment) this behaviour, when combined with repetitive chomping, does appear to provide unambiguous evidence of travel sickness (as previously reported in Randall & Bradshaw 1998). However, it should be stressed that instances of foaming and chomping might easily have been missed since pigs may have been obscured by others and, on a number of occasions, individuals were only noted as travel sick after the sound of retching was detected which allowed subsequent location and individual identification.

There was no relationship between the concentration of plasma LVP at exsanguination and incidence of travel sickness during the journey. Bradshaw *et al* (1996b) found that symptoms of travel sickness during the journey appeared to be associated with elevated concentrations of plasma LVP. This supports Forsling *et al* (1984) who found that exposure to vibration and noise also led to elevated plasma LVP concentrations. In addition, it has been shown that vasopressin release is stimulated in other species (man – Miaskiewicz *et al* 1989; monkeys – Verbalis *et al* 1987; sheep – Ebenezer *et al* 1989; pigs – Parrott *et al* 1991) following intravenous injection of cholecystokinin, a gut/brain peptide which induces emesis (Levine *et al* 1984; Verbalis *et al* 1987; Parrott *et al* 1991). Thus concentrations of LVP, in particular, may have been a reliable indicator. There is no evidence that concentrations of plasma cortisol and beta-endorphin relate to travel sickness but these hormones have been related to the level of stress during transport (eg Geers *et al* 1994; Geers 1995; Bradshaw *et al* 1996a, b) and at slaughter (Warriss *et al* 1994; Barton-Gade *et al* 1996a). However, hormone concentrations did not correlate with meat quality parameters in the present study, which generally supports the findings of other studies (eg cortisol, Warriss *et al* 1994; cortisol and beta-endorphin, Barton-Gade *et al* 1996a). In all cases there are difficulties in relating stress hormone concentrations at exsanguination to behaviour during the journey or subsequent meat quality because the process of loading/unloading and slaughter can be stressful and may result in changes in the concentrations of these hormones.

LVP concentrations at exsanguination were generally higher than those recorded before loading and during transport (Bradshaw *et al* 1996b). However, Forsling *et al* (1984) showed that pigs subjected to running disturbance (being chased around their pen for a few minutes and then restrained) showed a six-fold increase in plasma LVP concentration. Thus the high concentration of LVP at exsanguination in this study was probably due to the period of driving through lairage and stunning, rather than any effects of the journey (although Bradshaw *et al* [1996b] found no increase in plasma LVP in response to tailgate loading and initial transportation). Concentrations of cortisol and beta-endorphin were generally higher than previously recorded pre-loading levels, but lower than those measured immediately in response to loading (Bradshaw *et al* 1996a, b) which is known to be stressful (Brown *et al* 1993).

White muscle has a predominantly anaerobic metabolism and is more susceptible to the PSE condition than red muscle which has a predominantly aerobic metabolism and is susceptible to the DFD state (Barton-Gade *et al* 1996). Therefore, both should be used when assessing meat quality. However, the situation is not clear cut and in the past different researchers have used different parameters. For example, Portuguese researchers may use a higher FOP value in order to classify PSE (Santos *et al* 1996) than British (eg Warriss *et al* 1994) or Scandinavian ones (Barton-Gade *et al* 1996b). The standardization of methods for the assessment of PSE and DFD is necessarily difficult; this study applied recently standardized methodologies which had been employed during the course of an EU project (Barton-Gade *et al* 1996b). Since PSE tends to be associated with short-term, acute stress, any incidence of PSE may be mainly associated with the effects of unloading and the time taken to the point of slaughter rather than with transport. However, none of the pigs in this study were classified as PSE by FOP measurements; all were classified by PQM values. Warriss *et al* (1994) have reported that PQM readings are unsuitable for categorizing the meat quality of individual carcases under UK conditions (but useful for indicating the relative incidence of PSE in large groups to monitor overall product quality) and these categorizations should therefore be addressed with some caution. Since DFD meat tends to be associated with a long lairage time (a long-term, less acute stressor), it may be more

directly attributed to the effects of the transportation process and occurred in approximately one-fifth of carcases in this study.

In the case of both PSE and DFD measurements, travel sick pigs did not exhibit particularly poor meat quality. This may be because travel sickness is a problem associated with vibration and balance, and not the physiological pathways which result in PSE and DFD meat. Another consideration is that the finding may be due to the relatively small number of carcases assessed. In studies which do not require the observation of the pig before slaughter and involve the assessment of carcases in the slaughterhouse, many hundreds may be examined (eg Guise & Penny 1989a, b; Warriss *et al* 1994; Barton-Gade *et al* 1996a; Nanni-Costa *et al* 1996). However, within the group studied, the sample of travel sick pigs (defined either as those individuals which retched/vomited or those individuals which foamed/chomped/retched/vomited) and the incidence of PSE or DFD meat was substantial enough to allow any direct relationship to be detected. Thus, it seems likely that travel sickness has little or no adverse effect on meat quality.

Animal welfare implications

Over a quarter of pigs retched or vomited during the course of the study which involved slaughter-weight pigs in mixed-sex social groups transported in a commercial livestock vehicle. Concentrations of plasma hormones (cortisol, beta-endorphin and LVP) at exsanguination could not predict which pigs had been the most travel sick during transport, or the incidence of poor meat quality. While travel sickness does not appear to result in poor meat quality, it is clearly a problem of poor welfare and further research is needed in order to establish how prevalent it is in normal commercial practice. In addition, identifying the vibration characteristics which cause travel sickness (Randall & Bradshaw 1998) might also allow future vehicle design to minimize its occurrence.

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