THE WELFARE OF SLAUGHTER PIGS DURING TRANSPORT

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Abstract

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The welfare of transported pigs can be compromised both by physical and psychological stresses. The animals' responses can be assessed using records of mortality and trauma, physiological and behavioural observations and, to some degree, by measurements of meat quality since this can reflect the animals' physiological state at death. These assessments may, therefore, be used as measures of animal welfare. During transport pigs show weight loss, increased circulating concentrations of catecholamines, cortisol and creatine phosphokinase (CPK), and an increase in heart rate and packed cell volume; sometimes there is evidence of dehydration. Increased levels of dark, firm, dry (DFD)meat after long transport reflect muscle glycogen depletion and possibly indicate some element of fatigue. There is experimental evidence that transport is aversive to pigs, which may be partially due to the fact that they become travel sick. Mortality in transport has ranged from < 0.1 to > 1.0 per cent in different European countries. Mortality is higher in more stress-susceptible breeds and at higher ambient temperatures. It is increased in pigs fed within 4h of transport, at higher stocking densities and after longer journeys at ambient temperatures greater than 10°C. Pigs may be fasted long enough before slaughter to prejudice their welfare through hunger. Long fasts may also reduce muscle glycogen levels and cause fatigue. Fighting between unfamiliar animals which have been mixed during the marketing procedure is also stressful, however, longer transport may actually reduce this problem by allowing animals to get used to one another under conditions in which it is difficult to fight.

Keywords: animal welfare, pigs, transport

Introduction

A large amount of research has been carried out on the effects of transport on pigs. Much early work was reviewed by Hails (1978). Our knowledge of the influence of transport on meat quality was subsequently summarized by Warriss (1987) and Tarrant (1989), and aspects of both welfare and quality by Lambooy and van Putten (1993). Recommendations and guidelines for handling pigs ante-mortem, including transport, have been given in Warriss (1994;1995a). Recently, interest has focused on the welfare of transported animals in general, partly because of the possibility of much longer journeys (especially in exported stock) with about 7 million pigs being exported every year within the European Union (Christensen *et al* 1994). Also, there is greater apparent awareness and concern by consumers about the ethical quality of the meat they eat (Warriss 1995b;1996a).

This review is an attempt to summarize the considerable body of information relating to the transport of slaughter pigs in the context of its implications for animal welfare. According to

Broom (1991), the welfare of an animal is 'its state as regards its attempts to cope with its environment'. Good welfare implies a state of well-being in regard to health and a lack of distress because the animal is coping easily.

The stresses of transport

The transport of pigs is an inherently stressful procedure. We can identify obvious physical stresses such as temperature extremes, vibration and changes in acceleration, noise, confinement and crowding. There are also psychological stresses like the breakdown of social groupings and mixing with unfamiliar animals, unfamiliar or noxious smells, novel environments, hunger and thirst, and fatigue. Welfare will be influenced by the combined magnitude of all these stresses and by the length of the journey. A short journey under poor conditions may compromise welfare as much as, or even more than, a long journey under good conditions.

Improving welfare centres on eliminating or ameliorating these stresses as far as possible. Often this has economic costs and therefore improvement may be restricted to the minimum commensurate with 'acceptable' welfare. The definition of 'acceptable' is problematic. An example is stocking density in transit: the more animals that are carried on a vehicle, the lower the unit cost. However, higher densities are associated with evidence of greater physical stress (Warriss *et al* in press) and higher mortality (Lendfers 1971) indicative of poor welfare. A compromise might therefore be suggested – that a particular mortality rate must be tolerated for the sake of economics. However, different parties will find higher or lower rates acceptable or not depending on their vested interests and their personal viewpoints.

Physiological responses of pigs to transport

The specific types of stresses associated with transport produce different kinds of response. Psychological stress promotes release of corticosteroids from the adrenal cortex. Many studies have documented increases in circulating cortisol in transported pigs (Dantzer 1982; Spencer *et al* 1984; Becker *et al* 1985; Nyberg *et al* 1988; McGlone *et al* 1993; Bradshaw *et al* 1996a) or corresponding decreases in adrenal ascorbic acid levels (Warriss *et al* 1983). Although pigs can become travel sick, there is debate as to the prevalence of travel sickness. Assessments by Riches *et al* (1996b) suggested a very low prevalence (1%) but may have been based on inadequate experimental methodology (Bradshaw and Hall 1996). Limited direct observations of pigs carried on rough journeys (Bradshaw & Hall 1996) indicated prevalences of around 20 per cent or more. It is unclear whether pigs find travel sickness as unpleasant as humans but they appear to respond similarly, showing elevated levels of the hormone vasopressin in their blood (Bradshaw *et al* 1996b).

McGlone *et al* (1993) found that in pigs transported for 4h, individual liveweight loss was negatively correlated with blood cortisol concentration. In other words, pigs which had a greater adrenal response to transport also lost more weight. Liveweight loss caused by transport per se is often hard to differentiate from the effects of food and water deprivation during the journey. However, Warriss *et al* (1983) found that pigs in a non-fasting state lost 0.6 per cent of their liveweight after 1h of transport and 2.3 per cent after 6h. Losses in liveweight may, at least in part, reflect loss of urine and faeces rather than of body tissue. Carcase yield (the weight of the saleable body parts, mainly consisting of muscle, fat and bone but excluding viscera) is a better indicator of losses of the substance of an animal's body. Carcase yield was significantly reduced by 2.1 per cent in the 6h group compared with yields from untransported control pigs. Some of this reduction may have been caused by dehydration, as the transported animals subsequently drank more water in lairage and had higher plasma total protein concentrations in their blood at slaughter.

Lambooy *et al* (1985) found that transport for 44h led to a reduction in the water content of the subcutaneous fat on the back and suggested that the pigs were metabolizing the water to compensate for the reduced intake during transport. Transport also led to an increase in packed cell volume (PCV), and elevated concentrations of glycerol and ketone bodies in the blood. The specific gravity of the urine increased and blood glucose levels were reduced. The changes in backfat composition, PCV and urine composition support the view that the animals were becoming dehydrated during the journey. The changes in concentration of glycerol, ketone bodies and glucose indicate that the pigs were having to mobilize fats to supply metabolic needs. A summary of some of the physiological effects of transport in pigs is given in Table 1.

Table 1 **A summary of some physiological effects of transport on pigs.**

Effect	Reference
Live and carcase weight reduced	Warriss *et al* 1983
Blood cortisol levels increased	Dantzer 1982
	Spencer *et al* 1984
	Becker *et al* 1985
	Nyberg *et al* 1988
	Dalin *et al* 1993
Adrenal ascorbic acid depleted	Warriss *et al* 1983
Plasma adrenaline increased	Dalin *et al* 1993
Plasma CPK[1] increased	Honkavaara 1989; 1995
Changes in heart rate	Schütte *et al* 1996
	Christensen and Barton Gade 1996
Increased plasma total protein	Warriss *et al* 1983
Increased PCV and specific gravity of urine	Lambooy *et al* 1985
Decreased water in fat	Lambooy *et al* 1985
Increased number of circulating polymorphonuclear neutrophils and lymphocytes	Dalin *et al* 1993
Puberty induced in gilts with delayed puberty	Dalin *et al* 1998

[1] Creatine phosphokinase

In North America, pigs are often marketed for further fattening at about 9 weeks of age when they weigh 20–30 kg. The marketing procedure involves a period of up to 24h when animals are without food and water, mixing with animals from other rearing farms and transported for long distances (often 500–1000 km) to the fattening units. This results in quite significant weight losses (Table 2). These weight losses do not result in long-term detrimental effects to the pigs, based on their subsequent growth and performance to slaughter weights (Brumm & Peo 1985; Brumm *et al* 1987; Jesse *et al* 1988;1990).

Table 2 **Losses in liveweight in young fattening pigs (20–30 kg) during marketing in North America.**

Reference	Liveweight loss (%)
Brumm and Peo (1985)	8.4-12.7
Brumm et al *(1987)*	10.9
Jesse et al *(1988)*	6.8
Jesse et al *(1990)*	1.8-11.8

In addition to the transport itself, loading and unloading are often stressful episodes for pigs, particularly if handling facilities are inadequate. Loading ramps which are set too steep (at > 20° to the horizontal) are an example of such inadequacies (Warriss *et al* 1991). Van Putten and Elshof (1978) showed that heart rate increased to the greatest degree in pigs subjected to various procedures simulating commercial practice, when the animals were made to climb ramps. An increase in heart rate to very high levels at loading, which gradually fall during transport and then increase again at unloading, is often reported (Augustini & Fischer 1982; Christensen & Barton Gade 1996).

The effects of transport on meat quality have been investigated by numerous authors and reviewed by Warriss (1987). The results are very dependent on the stress-susceptibility of the pigs. The stress associated with even very short journeys can increase the incidence of pale, soft, exudative (PSE) meat in very stress-susceptible pigs, but more stress-resistant genotypes may show little or no effect of transport for moderate distances under good conditions. However, all pigs will show evidence of muscle glycogen depletion after longer journeys, particularly under poor conditions, and a higher incidence of DFD meat. In man, muscle glycogen depletion is associated with feelings of fatigue (Newsholme *et al* 1992) and it seems reasonable to think that pigs would respond similarly. Transport associated with increased levels of DFD might therefore reflect greater fatigue among the animals. For example, Malmfors (1982) reported that DFD incidence doubled in long transports (exceeding 90km) compared with short journeys (under 35km). Similarly, Heinze *et al* (1984) showed that as transport distance increased from less than 50km to more than 100km the frequency of carcases with higher than normal ultimate pH values increased from 23 per cent to over 30 per cent. The conditions under which the animals are carried will obviously be very important, but the implication is that long transport can fatigue pigs.

Mortality during transport

Even if an individual does not die, it is likely that its welfare will be reduced when overall mortality rates are high. Mortality during transport therefore reflects the welfare of all animals because it is usually determined, at least in part, by transport conditions. Death can occur either during the journey (DOAs – dead on arrivals) or subsequently in lairage (DIPs – dead in pens). The proportion of DIPs varies but averages range from 15 per cent (Warriss & Brown 1994) to 20 per cent (Allen 1979). It is normally assumed that pigs dying in lairage usually do so as a result of previous transport.

The effects of genotype and temperature

Two factors are particularly important in determining mortality rates in transported pigs. The first is genotype, the second is ambient temperature. The influence of genotype complicates the interpretation of the influence of other factors. So, a large part of the variation in actual mortality rates seen in different European countries (which range from < 0.1% to > 1.0%) can be explained by differences in the inherent stress-susceptibility of the pig population in each. Breeds susceptible to stress, such as the Pietrain and Belgian Landrace, or genotypes containing genes from these breeds, are much more likely to die in transit (Lister *et al* 1981).

Stress-susceptibility is closely associated with presence of the 'halothane' gene (named for the test originally used to detect its presence, in which animals with a double recessive gene show extreme sensitivity to the anaesthetic gas). In the past this gene has been inadvertently selected for, in the quest for leaner, more muscular carcases. This is illustrated well by data given in Hails (1978) for various studies on the mortality of pigs during transport in the Federal Republic of Germany (Figure 1). There was a rapid rise in mortality between 1953 and 1974 accompanying strong selection for leaner carcases. Conversely, selection against the halothane gene in breeding stock reduces mortality among the slaughter population. This is illustrated in data from Sweden (Petersson & Gahne 1988). Between 1982 and 1987 the number of halothane-positive boars (sires) in the population was substantially reduced in both Landrace and Large White breeds. The mortality rate in transported pigs dropped correspondingly from 0.22 to 0.08 per cent.

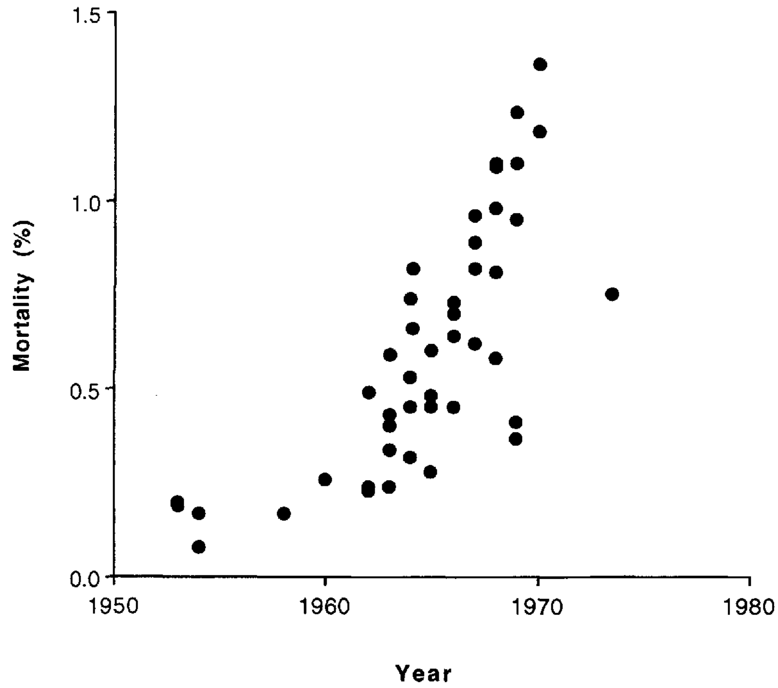

Figure 1 **Increase in the percentage of transport deaths between 1953 and 1974 in the Federal Republic of Germany. (Based on figures given in Hails (1978); the data came from 11 different studies.)**

There is a curvilinear relationship between mortality rate and ambient temperature (Allen & Smith 1974; Warriss & Brown 1994). In studies carried out in northern European countries, when the average daily temperature is below 10°C the incidence of mortality is low; at daily averages of between 10°C and 18°C it rises gradually, and above 18°C there is a very rapid increase in the number of pigs dying. It is not clear whether this relationship holds in the southern, hotter parts of Europe. However, in Spain there is little evidence of seasonal variation in mortality attributable to ambient temperature (Guardia *et al* 1996) but this is because special precautions are taken in the hotter months. These take the form of not mixing unfamiliar pigs, showering during transport and undertaking journeys at night. Pigs reared under conditions of high ambient temperature may also become acclimatized to them. Based on a careful analysis of mortality data, Smith and Allen (1976) found that losses during the August to December period in the UK were slightly less than those in the January to July period at the same temperature. The pigs killed between August and December would probably have experienced slightly higher temperatures during rearing. Smith and Allen therefore suggested that to reduce mortality it could be desirable to keep pigs at as high a temperature as possible in the last days before transport to slaughter.

In northern Europe, the relationship between mortality and temperature leads to a well-defined, seasonal effect with more pigs dying during the summer months (Lendfers 1970; Allen & Smith 1974; Fabiansson *et al* 1979; Warriss & Brown 1994). Pigs are sensitive to high temperatures, probably because they are thought to be unable to sweat effectively and can lose heat only by increasing respiratory frequency – panting (Ingram 1964) – or by wallowing to achieve evaporative cooling. The latter is obviously not possible during transport. The combined effects of genotype and temperature probably explain the variation in transport mortality rates seen throughout Europe (Table 3). The effect of humidity is unclear. Smith and Allen (1976) could find no correlation between mortality and relative humidity of the outside atmosphere. However, the work of Abbott *et al* (1995), based on reports from vehicle drivers, indicated that most deaths occurred when the weather was described as hot and wet.

Table 3 Pig genotype and transport mortality in some European countries. (Data from Warriss 1995a; information for Spain from Gispert *et al* 1996.)

Country	Genotype	Percentage mortality
Denmark	SR	0.03
UK	SR	0.07
Italy	SR	0.10
The Netherlands	SR	0.16
Portugal	Mixed	0.16
Spain	Not known	0.22
Belgium	SS	0.30
Germany	SS	0.50

SR pig population mainly stress-resistant
SS pig population mainly stress-susceptible

The effect of time of last feed

The prandial state of the animal is also important to some degree in influencing mortality. Pigs should not be transported too soon after feeding since mortality is higher under these circumstances, partly, it has been suggested, because a full stomach can reduce the diameter of the vena cava, impairing venous return and leading to circulatory insufficiency (see Warriss 1994). Löhr (1970) reported that the weight of the stomach and its contents was very much higher in pigs which died in transport to livestock markets than in comparable animals which did not die in transport.

It has been recommended that the pigs' last feed should be arranged for between 4h and 12h before loading (Warriss 1994). However, some recent work now suggests that 4h may be too short a time to prevent pigs vomiting during transport (R H Bradshaw and D M Broom personal communication 1996), at least on vehicles showing poor vibrational characteristics. What the minimal interval should be is still unclear. In a study of 21 000 transported pigs Robertson (see p 453 of English *et al* 1988) found a much higher mortality rate (0.67%) in pigs loaded 2h–6h after their last feed than in those loaded after 6h–12h (where it was only 0.13%), or longer than 12h (where it was 0.17%). Sains (1980) found that mortality in pigs not fed on the day of transport was 0.06 per cent compared with 0.09 per cent in pigs fed on the day of loading. In a study reported in Gispert *et al* (1997) in which the effects of feed withdrawal for less than 12h, 12h–18h or greater than 18h on mortality was measured in five slaughter plants, the lowest overall mortality occurred in the 12-18h group. Less than 12h, as well as greater than 18h of food deprivation, both increased losses although there was some variation between plants.

Other factors affecting mortality

Marginally more pigs die on the bottom deck of transporters than on the top or middle decks in both winter and summer (Sains 1980; Riches *et al* 1996a). Most deaths occurred in the pen immediately behind the cab, possibly because of poorer ventilation of this part of the vehicle (Sains 1980). This fits in with the results from a previous Meat and Livestock Commission study conducted by Cambac JMA Research, in which it was found that pigs travelling in this pen had higher concentrations of cortisol in their blood at slaughter (42 ng ml^{-1}) than pigs travelling in the other pens (15–17 ng ml^{-1}) suggesting that they were more stressed (Meat and Livestock Commission 1993). A survey of 12 000 pigs transported in South Africa (Henning 1993) found that dividing vehicles by transverse partitions into smaller pens (as is standard in the UK) reduced mortality, as did having the vehicle exhaust at the back or side. Mortality rates were slightly higher in double- than in single-decked trucks.

Higher stocking densities are associated with higher mortality. Lendfers (1971) found that loading densities exceeding 1.2 pigs m^{-2} led to more deaths. Robertson (see p 453 of English *et al* 1988) found that mortality was highest (0.54%) in groups of pigs carried at the 'recommended' or higher stocking densities of vehicles, decreasing progressively as stocking density was reduced from 90–99 per cent of recommended level (with 0.34% mortality) to 80–89 per cent (with 0.17% mortality). Recent work from Spain (Gispert *et al* 1996) tends to support these results: in a comparison of pigs transported at densities of less than or greater than 0.4 m^2 pig^{-1} carried out in four slaughter plants, there was either no effect on mortality (in three plants) or a highly significant increase from 0.04 per cent to 0.77 per cent (in one plant). A recent survey of UK commercial practice (Riches *et al* 1996b) also found higher mortality in loads of transported pigs that were stocked above the average (239 kg m^{-2} [or 0.42 m^2 $100kg^{-1}$]).

There is also some evidence of greater mortality with longer transport. In journeys of between 99 miles (or less) and 300 miles(or more), mortality increased progressively from 0.21 per cent to 0.65 per cent (see Robertson, on p 453 of English *et al* 1988) but other workers have found no evidence of a distance effect (Smith & Allen 1976; Sains 1980; Riches *et al* 1996c). The different findings could be explained by the interaction between ambient temperature and distance identified by Lendfers (1971): at temperatures below 10°C, travel distances ranging from under 5km to over 45km had no effect on mortality; however, at temperatures of 10–15 °C, or above 15°C, deaths were more frequent on longer journeys.

Very long distance transport of pigs

The influence of very long journeys (≥ 24h) on pigs has been addressed by relatively few studies. Most work has been carried out by Lambooy and his colleagues in The Netherlands, probably reflecting the importance of the export trade of pigs from that country to southern European countries such as Italy. Pigs exported from The Netherlands to Italy may be in transit for 2–3 days, with conditions often varying from hot sunshine during the day to very cold nights (Lambooy 1988).

Effects on mortality and weight loss

Lambooy's studies have investigated variation in a number of factors including journey length, stocking density, ventilation and the potential value of providing water to the pigs during the journey. Both actual commercial journeys and experimental journeys have been examined. Two important measurements were of mortality rates and the loss in liveweight of the animals. Results for these, together with information from Markov (1981) quoted in Lambooy (1983), are summarized in Table 4. Two things are apparent. First, although the range of mortality values is large (0.0%–2.8%), mortality tended to be higher than normally found in short journeys (0.03% –0.22%, see Table 3) in European countries. Second, the loss in liveweight was also large (3.5% –8.0%) in journeys ranging from 25h to 44h, although not much larger than would be expected assuming that the loss was mainly accounted for by lack of food, and that the average rate of loss in liveweight under fasting conditions is 0.2 per cent of initial weight h^{-1} (Warriss 1985;1993).

Table 4 **Summary of the effects of long distance transport of pigs on mortality and liveweight loss.**

Reference	Journey time	Distance	Stocking density or rate	Mortality (%)	Liveweight loss (%)
Markov (19981)	60–72h	–	–	0.17	10.2
Lambooy (1983)	26–31h[1]	–	0.5m^2 pig^{-1}	0.087[6]	5.0–5.5
Lambooy *et al* (1985)	44h[2]	–	0.33-0.65m^2 100kg^{-1}	0[7]	8.0
Lambooy (1988)	28h–35h[3]	1500km	~0.36m^2 100kg^{-1}	0.34[8]	6.0-7.8
Lambooy (1988)	25h[4]	1300km	~0.47m^2 pig^{-1}	2.8[9]	4.0
Lambooy and Engel (1991)	25h[5]		0.39–0.59m^2 pig^{-1}	0.15[10]	3.5

– not known
1 six international journeys
2 one experimental journey
3 three international journeys
4 six experimental journeys
5 11 international journeys
6 One pig out of 1148 carried in six journeys from The Netherlands to Italy
7 no pigs died during the journey but two died before unloading for slaughter
8 two pigs in one journey out of three, in which a total of 597 pigs were carried
9 five pigs out of a total of 180 carried in three journeys
10 one pig in 11 journeys

A contributory factor to the high mortality in some of the experimental journeys was that, unlike the commercial situation, pigs were not selected for soundness before transport, with any unfit animals being removed. Nevertheless, the observed mortalities provide evidence that welfare may well have been compromised in these long journeys. The liveweight losses imply that the pigs would have been hungry and possibly dehydrated. Direct evidence for the effects of fasting and water deprivation (leading to the mobilization of body energy reserves and dehydration) comes from increases in blood PCV and glycerol concentration, in the numbers of ketone bodies and in the density of the urine, in pigs transported for 44h (Lambooy *et al* 1985). In addition, this study found that transported pigs had a reduced water content of their subcutaneous fat, suggesting that they were mobilizing it to replace water lost from other parts of their bodies. The pigs also had higher ultimate pH values in their muscles, suggesting glycogen depletion and, possibly, fatigue.

Potential benefits of provision of drinking water in transit

In two studies (Lambooy 1983; Lambooy *et al* 1985) the potential benefits of providing water continuously during at least part of the journey by installing nipple drinkers in some pens was assessed. A surprising finding was that the pigs drank only very small volumes of water. In journeys of 26h–31h they consumed an average of only 0.65l per animal (Lambooy 1983) and on a journey of 44h, less than 5.4l – some of which was spilled rather than drunk (Lambooy *et al* 1985) – compared with a predicted normal water consumption of 7–20 l day^{-1}. These low consumptions were reflected in the findings that there was no effective influence of water provision on liveweight losses during the journeys in either study.

Lambooy (1983) suggested that possible reasons for the pigs not drinking included stress, fatigue, lack of food, vibration of the transporter, unfamiliarity with nipple drinkers and physiological adaptations to transport such as use of tissue water and reducing urine volume. It is conceivable that animals do not drink because they are suffering from travel sickness, but it seems unlikely that all pigs should have been affected in this way rather than a few individuals. Continuous provision of water did affect some meat quality measurements: in particular reducing some initial pH values and increasing rigor scores in the meat (Lambooy 1983) but overall, and rather surprisingly, there appeared to be few, if any, benefits of water provision.

Transport conditions and vehicle design

The welfare of pigs in transit is determined by the conditions under which they are carried as well as the length of the journey. Stocking density has already been considered in relation to mortality rates. The effects of different stocking densities on pigs, and the choice of appropriate densities, has recently been reviewed (Warriss 1998). Current legislation in the UK (*The Welfare of Animals [Transport] Order, 1997*) and EU Directive 95/29/EC, specify that under most normal circumstances pigs must have sufficient space to lie down during transport. Direct measurements and observations of pigs at different stocking densities suggest that this is equivalent to about $0.4m^2$ $100kg^{-1}$ for normal slaughter pigs weighing 90-100 kg. Slightly higher densities may be acceptable for very short journeys but space allowances of about $0.3m^2$ $100kg^{-1}$, which are sometimes seen in commercial transport, lead to physical stress. High densities in long journeys reduce meat quality in a manner which implies muscle glycogen depletion and, possibly, fatigue (Lambooy *et al* 1985).

Other important physical factors that may influence the acceptability of transport conditions are vibration and noise. Vibration is potentially an important source of stress during transport – although currently we have little information on the frequencies and magnitudes of vibration which are important. Randall *et al* (1995b) have made a comparative study of the vibration occurring in four different sorts of transporter. Vibration frequencies in the vertical direction ranged from about 1-4 Hz and in the lateral direction from about 2–16 Hz. Preliminary observations (Perremans *et al* 1995) suggest that pigs respond to vibration in a similar way to humans. Based on analogy with human experience these authors concluded that the vehicles examined by Randall *et al* (1995b) would have provided rides ranging from 'very uncomfortable' (in a small, towed, twin-axle trailer capable of carrying about 10 pigs) to 'not uncomfortable to a little uncomfortable' (in a large, fixed-body transporter with air suspension). Of course, other factors of importance in determining pig comfort by influencing vibration will be the condition of the road surface, the speed of the vehicle, the qualities of the driver and the length of the journey, and possibly the insulating characteristics of the flooring and bedding.

There is good evidence that pigs find vibration aversive (Stephens *et al* 1985; Stephens & Perry 1990), based on the results of experiments using operant conditioning techniques; and that high intensity vibration is more aversive than low level vibration. It was also found that vibration was more aversive when pigs had eaten a large, rather than a small, meal immediately before testing, although there was some evidence that the hunger (presumably associated with a 24h fast) added to the aversiveness of vibration (Stephens & Perry 1990). The implications are that for their comfort, pigs should be fed (but fed just a small meal) before transport, and that the degree of aversiveness of vibration can be influenced by other factors. Rutter and Randall (1993) have used similar operant conditioning techniques to investigate the differences in aversiveness of different frequencies of vibration to broiler chickens but similar results are not yet available for pigs. The implications of vibration for animals have been discussed fully by Randall (1992) and his colleagues (Randall *et al* 1995a).

Humans can respond to vibration with feelings of motion sickness, discomfort or fatigue. Vibration also causes much of the noise in livestock transporters. Levels of 90dB on the A scale[1], or 115dB on the linear scale, have been recorded inside vehicles during the transport of lambs (Knowles *et al* 1993) and it is likely that similar noise levels are common in pig transporters. The effects of this noise on pigs are unclear. In the experiments described by Stephens and Perry (1990), noise alone at a level of about 80–90 dB was not aversive enough to cause the pigs to switch it off. However, there is some evidence that under particular conditions pigs may dislike noise and further research is needed in this area.

Consequences of food and water deprivation during transport

Transport is associated with the deprivation of food and water, which may be stressful, potentially leading to hunger, fatigue and dehydration. The deprivation may extend beyond the duration of the journey. It is recommended that pigs are not fed immediately before transport and a minimum interval of 4h between the last meal and loading has been suggested (Warriss 1994;1995a). As has been mentioned previously, this is partly because pigs with full guts show higher mortality in transport (Warriss 1994) and may also be more prone to suffering from travel sickness (Lambooy & van Putten 1993). However, in practice, short fasting times are uncommon and very long periods of food deprivation before slaughter may occur.

A survey of 370 pig producers in Northern Ireland (Moss 1986) showed that 22 per cent fed their animals a final meal on the morning of delivery to the slaughter plant, 54 per cent fed them the evening before delivery and 24 per cent fed them on the morning of the day before delivery. This equates with an overall average period without food of about 14h (Warriss & Bevis 1987) and agrees with the findings of a Meat and Livestock Commission survey for Great Britain

[1] Noise or sound levels can be measured on several scales. The linear scale measures sound level across the whole frequency range; the A scale weights the sound level so that it is equivalent to that which is audible to the human ear.

(Sains 1980). By combining this period of food deprivation before transport with that between leaving the farm and slaughter, given by Warriss and Bevis (1986), the total time without food can be estimated. This agrees well with direct estimates based on a survey of liver glycogen concentrations from pigs killed at four plants (Warriss & Bevis 1987). These authors estimated that 75 per cent of the pigs had been fasted for more than 8h, 50 per cent for more than 18h and 25 per cent for over 30h before slaughter – and suggested that a significant proportion of pigs were without food for long enough for this to be prejudicial to their welfare.

Lambooy and van Putten (1993) recommended that before long journeys (≥ 24h), feeding the pigs with a thin porridge made of one part of feed with a high sugar content and three parts water would reduce liveweight losses from the 5–6 per cent or more seen in non-fed animals to about 3 per cent. Presumably this would be correspondingly beneficial for pig welfare. Guise *et al* (1992) have suggested that gastric emptying may be delayed in some way by the process of drafting out and transporting pigs but it is unclear what, if any, consequences this might have.

Without food, pigs begin to lose liveweight very soon at a rate of about 0.2 per cent h^{-1} (Warriss 1985;1993). Part of this loss is urine and faeces, but carcase and liver weight reduction, reflecting loss of body substance, begins between around 9h and 18h, respectively, after the last meal. The carcase weight loss averages about 0.1 per cent h^{-1}. Associated with the liver weight loss is a reduction in liver glycogen content. This follows a logarithmic pattern (Warriss & Bevis 1987) so that very little remains after 24h, over two-thirds having been lost in the initial 12h. It is likely that pigs are feeling very hungry by this time. Muscle glycogen is also lost with longer fasting. Pigs with lower concentrations of glycogen in their livers, indicative of longer food withdrawal times before slaughter, tended to have less glycogen in their muscles and a higher ultimate pH (measured 24h after death) in their meat (Warriss *et al* 1989).

Water deprivation for prolonged periods is less likely to occur than food deprivation, as pigs generally have access to water until immediately before transport and subsequently in lairage. However, there is some evidence of dehydration occurring after only short journeys (Warriss *et al* 1983), although pigs seem reluctant to drink during transport even when water is offered (Lambooy 1983). It is therefore not clear whether pigs become particularly thirsty under these conditions.

Fighting between unfamiliar pigs during transport

Stable social hierarchies develop in groups of pigs reared together. These hierarchies are disrupted when unfamiliar animals are mixed together, as often happens during the marketing procedure in order to collect together uniform batches of pigs for slaughter. Individuals in the mixed groups frequently fight to establish new dominance orders. This leads to skin lacerations, particularly in the shoulder region, which can be severe. The animals also show elevated circulating concentrations of cortisol and creatine phosphokinase (CPK), and evidence of muscle glycogen depletion, indicating that fighting is a stressful experience (Warriss 1995a). About 40–50 per cent of slaughter pigs show some evidence of fighting, although the prevalence of animals with skin damage serious enough to lead to their carcases being commercially downgraded is much less – probably between 5–10 per cent (Warriss 1996b). Boars (entire males) tend to be more prone to fighting than females or castrates. Warriss (1984) found that boars were between 1.3 and 2.5 times as likely to produce carcases that were downgraded because of serious damage than non-boars.

Other factors which are thought to influence aggression and fighting include hunger, group size and the size range between mixed groups. When mixed groups of pigs are free to fight there is generally an increase in the severity of the consequences the longer the animals are in contact. So, longer lairage increases the amount of fighting damage to carcases, with animals held overnight in particular showing more damage (Warriss *et al* 1995). Interestingly, longer times in transport may not be associated with more fighting, probably because it is difficult to fight and maintain a footing in a confined space on a moving vehicle. In fact there is some evidence that longer transport times may reduce subsequent fighting by enabling individuals to get used to one another under circumstances which do not allow them to fight (Warriss 1996b). This would fit with the findings of Moss and Trimble (1988) who showed that mixing pigs for up to 1h in a restricted space (0.35 m^2 pig^{-1}) before transport, in comparison with mixing them in an open yard (> 25 m^2 pig^{-1}), significantly reduced skin damage.

It has been suggested (see Warriss 1995a) that providing pigs with more space during transport, especially allowing them 0.5 m^2 $100kg^{-1}$, could lead to more fighting for the same reason as above. Pigs transported at high stocking densities (> 0.39 m^2 $100kg^{-1}$) may have too little room for ease of movement to encourage fighting. There is, however, little or no evidence that low stocking densities promote fighting in practice.

Conclusions and animal welfare implications

Transport is an inherently stressful procedure and elicits characteristic physiological stress responses. The impact of the stress can be reduced by limiting the length of journeys and by ensuring transport conditions are as good as possible. These conditions (also) encompass marketing procedures associated with, but not directly relating to, the journey itself. They include adequate preparation of the animals for transport, controlled prior access to feed and water, minimal disruption to social groups and adequate loading facilities.

When examining the welfare of pigs in relation to transport it is important to consider all aspects of welfare and the significance of all changes to handling procedures associated with transport. For example, an ideal pre-transport fasting time is one which balances the requirement to avoid hunger both with that of preventing or ameliorating travel sickness, and with reducing transit deaths to a minimum. Breeding and selecting for more stress-resistant strains or genotypes of pig would improve welfare by reducing mortality and the metabolic consequences of transport stress. In general, improved conditions of transport and associated handling are likely to improve carcase quality and reduce mortality as well as improving other aspects of pig welfare. However, it is essential that prescribed conditions and handling procedures are universally and uniformly applied, and compliance with relevant legislation enforced.

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