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Welfare Aspects of the Transport by Road of Sheep and Pigs

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That transport can be stressful to pigs and sheep has been inferred from behavioral and physiological measurements. Duration of journey is more likely to cause stress in pigs than in sheep, but loading and the start of travel are stressful to both. Vibration, related to vehicle design, and the jolting, shocks, and sudden impacts caused by road conditions and manner of driving, are probably of more importance than noise. Ventilation and stocking density can modulate the effects of ambient temperature, which may influence meat quality in pigs. Deprivation of food and water does not appear to stress sheep unduly, but this can become a serious welfare concern in the case of pigs. However, most journeys undertaken by pigs in the European Union are relatively short. In sheep, transport may follow soon after other stressful experiences such as weaning, shearing, handling, or marketing; the interaction of these factors in causing cumulative stress has not been studied. In pigs, fighting after the mixing of previously unacquainted animals is well known to be a welfare issue that can compromise meat quality. Considering the public interest in livestock transport and the large amounts of money involved, surprisingly little research has been done in the area, and more is urgently needed for legislation and welfare codes to be soundly based on scientific knowledge.

Transport of livestock is a difficult subject to study because any response that an animal may make could be due to any number or combination of factors. These include novelty, handling, social mixing, dehydration, hunger, noise, vibration, and the experience of the animals before transport. It is possible that what might be presumed from an anthropomorphic viewpoint to be a particularly stressful aspect of transport may be found, on investigation, to be unimportant; the converse also may be true.

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If a physiological response is demonstrated as a consequence of transport, for a welfare insult to be proven, it must be shown that this response is outside the normal range and, therefore, is indicative of the homeostatic system of the animal failing to cope. Death indicates the ultimate failure of this system; however, this is most unusual for sheep and uncommon for pigs during road transport (mortality rates of sheep and pigs cited in the study of Knowles, Maunder, Warriss, & Jones, 1994, were 0.0182 and 0.07 percent, respectively). Other measures of welfare are more appropriate.

WELFARE MEASURES

This article considers the challenges that a sheep or pig may face during transport and related events, and attempts to draw some conclusions as to whether these challenges indicate welfare problems. Reference is made to work with other species when this illustrates the kind of study that might be made with sheep or pigs. Previous work on one of the world's most spectacular mammalian livestock operations, the transport of approximately 7 million live sheep from Australia to the Middle East each year (Bailey & Fortune, 1992; see also Black, Matthews, & Bremner, 1994), is not reviewed. The emphasis is on road transport of sheep and pigs within the European Union; earlier work was reviewed by Hails (1978) and Lambooij and van Putten (1993).

One available catalog of measures of welfare is that of Broom and Johnson (1993). They distinguished short-term and long-term responses to stressors. In animals that are being transported prior to breeding or further rearing, long-term responses are important, which is not the case in animals that are going to slaughter. Most of this article is concerned with short-term responses, except that if animals take a long time to recover, this could give some insight into the degree of stress incurred. For example, the observation of Kim, Jackson, Gordon, and Cockram (1994) that sheep from markets lie down, in lairage at the abattoir, more readily than do those from farms, could indicate that transit through markets is fatiguing.

Observations

Sometimes observations of the effects of transport stress are of special interest because they provide insights into the physiology of stress. For example, Smart, Forhead, Smith, and Dobson (1994) reported that transport stress delays the oestradiol-induced luteinizing hormone (LH) surge in postpartum ewes by about 3 hr, which, although of limited practical significance, does suggest modes of action of stress upon the secretion of LH (Dobson & Smith, 1995). In sows, transport stress can increase LH activity (Rojanasthien, 1989).

Short-term responses may be behavioral or physiological. There is much scope for the further development of behavioral indicators of stress, and, at present, the methods used to record and analyze behavior are very diverse. Animals often show
individual differences in physiology and behavior, and observational and analytical methods for dealing with, and deriving useful general information from, such differences need to be developed further (Martin & Kraemer, 1987).

Physiological responses, such as changes in heart rate (HR), respiratory rate and body temperature, haematocrit (also known as packed cell volume), adrenal and pituitary hormones, catecholamines, enzymes, and metabolic products, as well as in muscle and carcass characteristics, can be examined. Hormone concentrations are usually assayed in blood plasma, but free cortisol is secreted in saliva and can be measured as well (Cooper, Trunkfield, Zanella, & Booth, 1989; Parrott, Misson, & Baldwin, 1989).

**Stressors**

Some works have defined stressors as, effectively, stimuli that activate the hypothalamic-pituitary-adrenal axis (Minton, 1994), promoting secretion of cortisol, corticosterone, adrenaline (also known as epinephrine), or noradrenaline (norepinephrine). As a result, abnormal increases in cortisol are commonly considered to indicate stress (Broom & Johnson, 1993). It is important to collect blood quickly, painlessly, and efficiently; McGlone et al. (1993) described how plasma cortisol concentrations increased in pigs in proportion to the time it took to collect samples from a penned group.

A number of researchers also have employed beta-endorphin as an indicator of stress in transport studies (e.g., Azaga & Rodway, 1995; Fordham, Lincoln, Ssewannyana, & Rodway, 1989; Geers, 1995; Geers et al., 1994; Shaw & Tume, 1990), but it seems less appropriate for studying long-term or chronic stress than for acute stresses like the loading of pigs (Bradshaw, Parrott, Goode, et al., 1996) or the brief exposure of sheep and possibly pigs to unfamiliar noise (Anil et al., 1993). Prolactin may, similarly, be more indicative of short-term than long-term stress (Broom, Goode, Hall, Lloyd, & Parrott, 1996). There are many examples of correlations in sheep between physiological responses, such as HR and plasma cortisol (Harlow, Thorne, Williams, Belden, & Gern, 1987), and between HR and behavior (Ballock, Penning, & Sibley, 1987; Ballock, Sibley, & Penny, 1988).

In a few studies, correlations between behavioral observations and physiological processes have been made; for example, elevation of plasma lysine vasopressin in pigs is associated with vomiting (Bradshaw, Parrott, Forsling, et al., 1996), while inhibition of rumination in sheep has been suggested to indicate travel sickness (Austin, 1996). Also, stress-related changes in immune function (Kelley, 1988) can be induced by transport (McGlone et al., 1993). As for most sheep and pigs, long-distance transport is quickly followed by slaughter. This is not of prime practical significance, but it does serve as an indicator that the animal has been subjected to stress. It is, therefore, always advisable to take many concurrent measurements when stress responses are being investigated (Broom & Johnson, 1993).
GENERAL EFFECTS OF TRANSPORT

Information on the stress effects of transport is available from four kinds of study:

1. Studies where transport, not necessarily in conditions representative of commercial practice, was used explicitly as a stressor to evoke a physiological response of particular interest (Horton, Baldwin, Emanuele, Wohlt, & McDowell, 1996; Smart et al., 1994).

2a. Uncontrolled studies with physiological and behavioral measurements being made before and after long or short commercial or experimental journeys (Becker et al., 1989; Becker, Neinaber, Deshazer, & Hahn, 1985; Dalin, Magnusson, Haggendal, & Nyberg, 1993; Dalin, Nyberg, & Eliasson, 1988; Knowles, Warriss, Brown, & Kestin, 1994).

2b. Uncontrolled studies during long or short commercial or experimental journeys (Hall, 1995; Lambooy, 1988).

3. Studies comparing animals that were transported with animals that were left behind to act as controls (Knowles et al., 1995; Nyberg, Lundstrom, Edfors-Lilja, & Rundgren, 1988).

4. Studies where the different stressors that impinge on an animal during transport were separated out either by experimental design (Bradshaw, Parrott, Goode, et al., 1996; Broom et al., 1996; Cockram et al., 1996) or by statistical analysis (Hall, Bradshaw, & Broom, 1995).

Some responses are frequently observed during transport, but it is not yet conclusively determined which aspect of transport induces them. For example, the travel sickness shown by pigs (Bradshaw, Parrott, Forsling, et al., 1996) could be due to noise, vibration, some other factor, or some combination of factors. It is frequently not obvious what control condition is appropriate for transport experiments, although controls are of course advisable for several reasons, including the need to take account of circadian rhythms in hormone secretion. For example, in pigs, plasma cortisol concentration is higher in the morning than in the afternoon (Becker et al., 1985), and in sheep, it is highest around 1:00 a.m. and lowest after 12:00 p.m. (Fulkerson & Tang, 1979).

In this article, responses are discussed under the headings that the authors believe to be appropriate. Emphasis is placed on the similarities and differences between species, although there has only been one study (Bradshaw, Hall, & Broom, 1996) in which responses of sheep and pigs to transport have been compared directly.

EFFECTS OF DURATION OF JOURNEY

For most pigs in the European Community, the journey to slaughter lasts less than 3 hr (Warriss, 1996). Within the United Kingdom, most sheep travel for up to 6 hr
ROAD TRANSPORT OF SHEEP AND PIGS (Knowles, Warriss, et al., 1994), but long-distance journeys are common (Hall, 1995). Experimental studies have either involved before and after measurements with journeys of different lengths (Knowles et al., 1995) or measurements during a journey. For pigs, studies of either kind are surprisingly few in number, partly due to the relative difficulty of obtaining blood from this species. Dalin et al. (1993), using 6 gilts of 134 kg body weight, drew blood samples through jugular catheters during a journey of 60 min. The samples showed increased concentrations of cortisol and adrenaline during transport.

Bradshaw, Parrott, Goode, et al. (1996), also using catheterized pigs (35 kg body weight), found cortisol to be increased, but the longer journey time (8 hr) led them to the conclusion that this rise, initially a response to loading, was maintained as a response to transport. Geers et al. (1994) took blood from pigs by venipuncture under anaesthesia before and after journeys of 2 hr and found plasma cortisol concentration to decrease or to remain the same; these results could be anomalous and attributable to their blood-sampling protocol. McGlone et al. (1993) used a similar protocol, but without anaesthesia, and discussed its possible shortcomings.

Broom et al. (1996) found that in catheterized sheep, an initial response to loading and the commencement of transport was virtually extinguished within 3 hr, and for the remainder of the journey (total duration 15 hr), stress responses were only slight. The long-distance journeys with pigs described by Lambooy (1988) do not make it clear whether 25 hr of transport is, of itself, stressful, though that article emphasized the importance of adequate space and ventilation. The longest uninterrupted journeys so far reported, using sheep, have been of 24 hr (Knowles et al., 1995).

**EFFECT OF NATURE OF JOURNEY: PHYSICAL AND ENVIRONMENTAL CONDITIONS**

**Novelty**

Following loading onto a vehicle, animals enter an environment that is usually novel for them. For sheep, information is lacking on general responses to novelty. However, Parrott, Lloyd, and Goode (1996) found a clear response of plasma cortisol when sheep were placed in a novel environment, whereas Reid and Mills (1962) found that sheep who were normally housed indoors had a consistently smaller increase in plasma cortisol concentrations after transport than those kept on pasture and suggested that transport was less novel to sheep who were accustomed to being enclosed. Conversely, the probability also exists that sheep raised indoors will be less physically fit than outdoor sheep (Tollersrud, Baustad, & Flatlandsmo, 1971), which could predispose the former to stress.

The nature of the endocrine response to novelty can be related to the general pattern of behavior, social organization, and lifestyle of the species in question (Hennessy, Mendoza, Mason, & Moberg, 1995). There can be clear differences
between breeds in behavioral responses to novelty. Romeyer and Bouissou (1992) found Romanov sheep—a relatively primitive breed from Russia with ewe body weight of 55 kg—to be more reactive than Ile de France sheep—a French breed with affinities to Merino and Leicester and ewe body weight of 80 kg (Lauvergne, 1986). A number of recent studies have investigated the effects of novelty in pigs (Day, Kyriazakis, & Lawrence, 1995; Hemsworth, Price, & Borgwardt, 1996; Jensen, 1994), although these are not specific to transport.

Vibration

Vibration has direct physiological effects and is a potent stressor; so far, most studies have been in poultry (Rutter & Randall, 1993; Scott, 1994). Certain frequencies are associated with certain responses; for example, in humans, a frequency of 0.2 Hz is most likely to evoke motion sickness (Randall, 1992). As yet, the responses of sheep and pigs to different frequencies are not known in detail. What is clear is that vehicles and trailers in common use differ considerably in the vibrations transmitted to the animals that they carry (Randall, Cove, & White, 1996; Randall, Stiles, et al., 1996).

Travel sickness, with symptoms including repetitive chewing, a slight “foaming” at the mouth, and frequent bouts of sniffing the air (Bradshaw, Hall, et al., 1996), has been noted when pigs are transported, and it may have been underrecorded in the past because very soon after vehicular motion ceases, pigs may reingest vomit (Bradshaw, Hall, et al., 1996). Subsequently, additional studies that have involved the direct observation of pigs during transport found that 33% of unmixed pigs (8 out of 24) retched or vomited during a 1½-hr journey (Bradshaw, Parrott, Goode, et al., 1996); this figure was 26% (13 out of 50) during a 4½-hr journey (Randall & Bradshaw, in press). In addition, Bradshaw et al. (1997) found that travel sickness did not appear to effect subsequent meat quality. However, the degree to which travel sickness is a problem in normal commercial practice remains unclear (Bradshaw & Hall, 1996; Riches, Guise, & Penny, 1996).

Forsling, Sharman, and Stephens (1984) have shown that exposure to vibration and noise leads to raised concentrations of plasma lysine vasopressin (LVP) in pigs, and nausea is associated with enhanced vasopressin secretion in man (Rowe, Shelton, Helderman, Vestal, & Robertson, 1987). It also has been shown that vasopressin release is stimulated in man (Koch, Sumney-Long, Bingaman, Sperry, & Stern, 1990; Miaskiewicz, Stricker, & Verbalis, 1989), monkeys (Verbalis, Richardson, & Stricker, 1987), sheep (Ebenezer, Thornton, & Parrott, 1989) and pigs (Parrott, Ebenezer, Baldwin, & Forsling, 1991) following intravenous injection of cholecystokinin, a gut/brain peptide that induces emesis. Thus, because vasopressin is a physiological correlate of nausea in animals that vomit, increased plasma LVP concentrations in pigs during transport may signal motion sickness.
(Bradshaw, Parrott, Forsling, et al., 1996), although clear evidence on sheep is not yet available (Hall, Forsling, & Broom, in press).

Sheep probably do not vomit (except on rare occasions when recovering from general anaesthesia, R. F. Parrott, personal communication, September 12, 1996), but raised concentrations of vasopressin (the ovine form is arginine vasopressin or AVP) nevertheless may indicate stress in this species, especially in the context of dehydration (Thornton, Forsling, Baldwin, & Delaney, 1987; Thornton, Parrott, & Delaney, 1987). No increase in LVP concentrations has been observed in pigs as a response to loading, but behavioral symptoms of travel sickness, apparent after 2 hr, coincided with a rise in hormone concentrations (Bradshaw, Parrott, Forsling, et al., 1996).

**Shocks and Impacts**

A journey can be characterized as “rough” or “smooth” by accelerometers fitted to the body of an animal (Cockram et al., 1996) or to the vehicle (Bradshaw, Hall, et al., 1996). Hall et al. (1995) reported preliminary results suggesting that, in sheep, HR may be increased during periods of a journey when there are many shock events such as occur when road conditions are poor or driving inconsiderate. Bradshaw, Hall, et al. (1996) also compared the behavior and salivary cortisol response of pigs and sheep during short (80-min) journeys, which were defined as rough and smooth. In both species, plasma concentrations of cortisol were higher on rough journeys.

**Noise**

Livestock transporters are, to the human ear, very noisy (90 dB[A] on average was metered within the trailer of an articulated livestock vehicle by Knowles et al., 1993), but data are not yet available to indicate clearly whether this causes stress. Sanhouri, Jones, and Dobson (1989), studying small groups of goats, considered that noise elicited more of a cortisol response than did motion. Weisenberger, Krausman, Wallace, de Young, and Maughan (1996) found that deer and mountain sheep (*Ovis canadensis*) showed a heart-rate response to very loud noises of short duration, but that habituation was rapid.

In contrast, experiments with operant conditioning (McAdie, Foster, Temple, & Matthews, 1993) suggested that the welfare of hens was adversely affected by loud noise, although experiments of this kind have not been reported in sheep or pigs. Anil et al. (1993) found an elevation in plasma β-endorphin but no change in plasma cortisol when sheep and pigs (of unspecified age) were exposed to a recording of abattoir noise for 30 min. During an exposure to noise of up to 20 min, piglets (15 kg body weight) showed increase in HR and changes in behavior (Talling, Waran, Wathes, & Lines, 1996).
It was concluded that pigs habituate to sound when no immediate threat or danger is identified. Preliminary findings of Hall et al. (1995) were that vibration is more likely than noise to stimulate increase in sheep HR.

**Orientation**

Clark, Friend, and Dellmeier (1993) observed that horses facing rearward were better able to maintain their balance during transport in a trailer than those facing forward, but there was no effect of orientation on plasma cortisol or HR. Extensive studies on this topic have not been made with sheep or pigs, except that Cockram et al. (1996) reported that sheep oriented themselves with "no clear preference."

**Loading**

Most studies of sheep and pigs have found stress to be high during loading and in the early stage of a journey. For example, cortisol secretion is stimulated in pigs by loading (Brown et al., 1993). In catheterized pigs sampled during an 8-hr journey, Bradshaw, Parrott, Goode, et al. (1996) found that plasma cortisol concentrations were highest during loading and declined after 5 hr to near control levels (recorded when pigs were loaded onto the vehicle, which remained stationary). Warriss, Bevis, Edwards, Brown, and Knowles (1991) demonstrated the importance for pigs of the loading ramp not being steep and of correct spacing of the transverse battens (cleats) that help animals to grip.

In the case of sheep, there has been little study of the loading process, although Broom et al. (1996) found clear evidence that the major stress imposed on sheep undergoing a journey of 15 hr was the herding and loading at the start. However, Cockram et al. (1996) found effects of loading were not consistent. Possibly this reflects differences between the two types of sheep in these studies (respectively, Clun Forest and Suffolk x Greyface).

A widely held opinion is that the less familiar sheep are with people, the easier they are to load into a lorry; this might have been predicted from the observation of Hargreaves and Hutson (1990) that sheep who are accustomed to people are less afraid of a person standing behind them and, therefore, move more slowly.

**Ventilation**

Randall (1993) has stressed the need for appropriate ventilation for livestock during transport. Lambooy and Engel (1991) found that meat quality was not influenced by degree of ventilation, or as a result of cooling the pigs with a water spray during the journey. Clearly, though, ventilation and stocking density will interact in some
way to modulate the thermal stress that will be imposed on pigs and sheep during transport, but a multifactorial study has not been conducted.

Temperature

The sensitivity of pigs to extremes of temperature is well known, but experiments on how ambient temperature interacts with other transport variables do not appear to have been reported, although there are many accounts of observations made during transport (Lambooij & van Putten, 1993). Lambooy (1988) found that the meat quality of pigs was affected by ambient temperature; higher ambient temperatures led to higher muscle ultimate pH. Guise and Warriss (1989) did not find such an effect, but this discrepancy is possibly due to differences in animals and experimental procedures.

Stocking Density

Stocking density is one of the variables that is most easily manipulated; it affords the means to mitigate the effects of high ambient temperature through provision of adequate ventilation, to regulate the generation of heat and the nature of convective air currents within the vehicle, and to provide the space that animals require because of their body dimensions and the behaviors they are permitted to perform during transport (Randall, 1993). On the basis of current practice and recommendations, Randall (1993) suggests this equation relating body mass: (M) to area required in m² (A): A = 0.021 M^{0.67} (i.e., for a 40 kg sheep, 0.249 m²). However, this takes no account of whether sheep are shorn or not. In commercial practice (S. J. G. Hall, personal observation, September 12, 1994) shearing increases the number of sheep that can be transported on a lorry by 25%.

In contrast to Guise and Warriss (1989), Lambooy and Engel (1991) found that stocking density did influence meat quality and recommended a density of 232 kg/m² (i.e., for a 110 kg pig, 0.47 m², which is slightly less than recommended by Randall, 1993).

Guise and Penny (1989a) pointed out that if pigs are to be transported at high stocking density, the use of electric goads does speed loading and there is less skin blemish, but there could be welfare problems; they noted signs of rectal prolapse (not necessarily an irreversible condition, but nevertheless indicative of stress) when pigs were densely stocked. Dense stocking might be expected to reduce the severity of fighting among unacquainted pigs, but this benefit must be weighed against the desirability of allowing the pigs enough space for lying.

Analysis of the welfare costs and benefits of stocking rates, in both species, is urgently required. Warriss (1996) presents current understanding of suitable stocking rates in pigs while Cockram et al. (1996) state, though without providing clear physiological evidence of a welfare benefit, that sheep should be stocked at a rate that permits them all to lie down simultaneously.
Location in Vehicle

Conditions within livestock lorries may depend upon location (Mitchell & Kettlewell, 1995). Preliminary experimental data are available (Barton-Gade, Christensen, Brown, & Warriss, 1996), which indicate that pigs transported on the lower tier of a two-tiered lorry had higher cortisol concentrations and evidence of poorer carcass quality than those transported on the upper tier.

EFFECTS OF LACK OF FOOD AND WATER

Body Weight

During transport, sheep lose weight, but this is not indicative of dehydration because of the sizable reserve of water in the rumen (Silanikove, 1994). Knowles et al. (1995) reported a loss of 8% after 24 hr of transport, most of which was incurred during the first 15 hr. In that study, the same proportionate loss was found in sheep kept in pens without food or water for the same time. After the experiment, the latter group recovered the lost weight more rapidly.

In an earlier study (Knowles et al., 1993), sheep transported for 14 hr or 24 hr showed the same loss of weight (6.7%), but control animals held in a pen for 24 hr lost only 1.5% of their initial weight. The transported animals continued to lose weight after transport, in spite of the availability of food and water, but after 96 hr, live weight was restored. In a commercial journey of 18 hr (Knowles, Warriss, et al., 1994), the loss of body weight was 4%. Hall, Schmidt, and Broom (1997) found the mean loss of live weight after 14 hr of confinement in a stationary trailer to be 5.7%; this varied considerably among individuals, and smaller sheep lost a higher proportion.

With slaughter pigs, Becker et al. (1989) observed a 3.19% loss of body weight during 11 hr of transport (Lopez, Jesse, Becker, & Ellersieck, 1991), which was similar to the body weight lost during a fast of 24 hr.

Plasma Osmolality and Stress Hormones

Plasma osmolality is a measure of the total osmotic force exerted by colloids and by noncolloidal electrolytes, which can be used as a measure of dehydration (Clemens, Schultz, Brumm, Jesse, & Mayaes, 1986). In both pigs and sheep, findings on changes in plasma osmolality during and after transport have not been clear-cut. In slaughter pigs, Becker et al. (1989) found that plasma osmolality was increased by transport, whereas Clemens et al. (1986) found that although weaner pigs showed signs of dehydration after 15 hr of transport, the data on plasma osmolality were not consistent with that observation.
In sheep, Knowles et al. (1993) found plasma osmolality had decreased after 14 hr of transport, but it then increased in lairage before reverting, after 48 hr, to the pretransport level. Knowles, Warriss, et al. (1994) found that plasma osmolality increased after a June journey of 24 hr into France, but not after an 18-hr journey in August. Knowles et al. (1995) found that after 24 hr of transport, osmolality had increased slightly, but there was no strong evidence of dehydration.

Parrott et al. (1996) deprived sheep of food and water in ambient temperatures of 7°C and 35°C for periods of 48 hr and found plasma osmolality remained unaffected, except when the sheep had access to food, but were deprived of water; in that case, it increased. A possible cause is that water could move from the plasma into the rumen when sheep feed—plasma volume is known to fall rapidly after dry food is eaten (Blair-West & Brook, 1969). In the same study, Parrott et al. (1996) investigated whether food and water deprivation led to a change in concentrations of stress hormones in sheep; they detected responses by prolactin and cortisol, but these were attributed to the novelty of the procedure rather than to the deprivation.

Packed Cell Volume

Haematocrit rises as an initial response to stress, presumably because the spleen contracts, forcing red cells into the circulation (Turner & Hodgetts, 1959), although it is conceivable that postural changes play a part (Eisenberg, 1963). In sheep, haematocrit usually falls below the resting value as transport proceeds (Broom et al., 1996), but in pigs under long-term dehydration, it rises again (Becker et al., 1989; Clemens et al., 1986).

Differences Among Individuals

Adverse reaction on the part of some pigs to halothane anaesthesia permitted identification of certain genotypes as being particularly stress-susceptible (Andersen, Jensen, & Barton-Gade, 1981; Webb, Carden, Smith, & Imlah, 1982). While it seems probable that the halothane gene predisposes pigs to death during transport (Warriss, 1996), the physiological mechanisms are not clear.

It is possible that pigs homozygous for the halothane gene show a greater elevation in HR in response to handling and stress (Geers et al., 1994), although Nyberg et al. (1988) found that the relation between halothane genotype and cortisol concentration was obscure. McGlone et al. (1993) found that pigs of low social status, when stressed by transport, showed suppression of their immune systems, and, on a similar theme, Geers (1995) reported an attempt to classify pigs according to the coping strategies they adopt during transport. Hall, Broom, and Kiddy (in press) found that sheep of upland breeds showed a stronger response of plasma cortisol than did those of lowland type.
Sometimes, an economic inducement is needed before improvements to welfare are made. A demonstration that better welfare means better meat quality would therefore be welcome to those seeking to improve welfare. At slaughter, the pH of muscle decreases from about 7.2 to its ultimate value of 5.4 to 5.7. But if muscle glycogen reserves are depleted before death, the formation post mortem of lactic acid is curtailed, and the ultimate pH may remain at 6.0, which results in dark, firm, dry meat (Warriss, 1982; Warriss, Bevis, & Ekins, 1989). This has been observed in sheep chased to exhaustion before slaughter, but not under more realistic conditions of exercise (Apple, Minton, Parsons, Dikeman, & Leith, 1994). In pigs, if the fall in pH is too rapid, the muscle proteins lose some of their ability to hold water, and pale, soft, exudative meat results (Hails, 1978).

Several physiological processes link reduced meat quality with stress such as occurs during transport. First, lesions such as bruises, scratches, and bites can reduce carcass value and cause a welfare insult (Guise, Penny, Weeding, & Hunter, 1991; Jarvis & Cockram, 1994, 1995; Warriss & Brown, 1985). However, Becker et al. (1989) assessed meat quality by several measures, including a taste panel, and found transport and fasting did not adversely affect meat quality, although the loss of body weight during those procedures was commercially significant.

McGlone et al. (1993) found that pigs (mean body weight 27.4 kg) that showed a high cortisol response to 4 hr of transport also tended to lose more body weight. From another perspective, Sensky, Parr, Bardsley, and Buttery (1996) reported how increases in plasma adrenaline concentration may reduce the potential of the calpain enzyme system to effect proteolysis, which is necessary for post-slaughter tenderization of meat.

EFFECTS OF EVENTS ASSOCIATED WITH TRANSPORT

Sometimes within the space of a few days, lambs are weaned from their dams, sent to market and then to an exporter’s premises, mixed with lambs from other farms, weighed, handled for assessment of conformation, ear tagged, clipped, and then loaded and sent on a long journey for further fattening or slaughter. There have been no studies on the relative importance of each of these events as stressors, and there is no body of informed opinion as to whether such stressful events should take place in quick succession or be separated. These events may be interdependent. For example, lambs who have been shorn benefit from reduced heat stress (Black & Chestnutt, 1992; Kirk & Alsop, 1989)—at least when they are housed. Whether this is also the case when they are closely packed in a lorry is another question.

In this connection, a decision of whether sheep should have enough space to lie down during transport should take account of the fact that shorn sheep spend more
time standing than do unshorn (Davey & Holmes, 1977). In many cases, lambs are not killed immediately at the conclusion of a journey, but are fed for a week or more before being killed. As shorn lambs have a higher concentrate requirement than do unshorn (Black & Chestnutt, 1992), there could be an economic penalty to be set against the economic advantage of transporting shorn lambs.

In the case of sheep and pigs, there is a lack of studies on multiple stressors, either acting concurrently or consecutively, although in poultry (e.g., McFarlane, Curtis, Simon, & Izquierdo, 1989), a fruitful experimental approach has been adopted, which has shown that when different stressors act concurrently, their effects are additive, not multiplicative or synergistic. Similar approaches have recently been applied to pigs (Geverink, Bradshaw, Lambooiij, Wiegant, & Broom, in press).

**Breaks During the Journey**

Research is urgently needed to determine whether welfare would be improved by a break during a long journey, with sheep and pigs being offered food and water either on or off the vehicle. For sheep, current U.K. legislation requires a break of 1 hr off the vehicle, with food and water on offer, after 14 hr of transport, which then may be followed by a further 14 hr of transport (Anonymous, 1995). This takes no account of the well-known (Knowles, Warriss et al., 1994) preference of sheep for food over water after a period of deprivation, and the clearly stated conclusion (Knowles et al., 1995) that a journey involving 24 hr of travel is best conducted without interruption by a break involving unloading.

Experiments have shown (Hall et al., 1997) that a break of 1 hr is likely to be of no benefit and may possibly pose a threat to welfare in that dehydration may become worse due to sheep having enough time to feed but not to drink. Pigs may travel for a maximum of 24 hr provided they have continuous access to water (Anonymous, 1995), though such provision may be of doubtful efficacy in practice (Lambooiy, Garssen, Walstra, Mateman, & Merkus, 1985). Further research is required to establish whether these stipulations are appropriate.

**Economic and Management Factors**

Economic and legal constraints determine how far the conditions of transport can be improved. Some of these background factors are discussed by Grandin (1993, 1994) and by Harris (1996). Welfare codes and statutory instruments are most likely to achieve improvements in welfare if they are devised with reference to biological reality and to the commercial pressures under which the livestock transport industry operates.
Mixing

Pigs who are unfamiliar with each other (when not being transported) fight; this leads to elevated levels of plasma and salivary cortisol (Geverink, Bradshaw, Broom, & Lambooy, 1996; Jensen, 1994; Parrott & Misson, 1989; Tan & Shackleton, 1989). Bradshaw, Parrott, Goode, et al. (1996) showed that pigs previously unacquainted with one another fought during transport and had raised levels of salivary cortisol compared with pigs who were familiar with each other. Mixing various groups of unfamiliar pigs at loading leads to carcass damage, which can be presumed to compromise welfare (Guise & Penny, 1989b). Confirming this, Warriss & Brown (1985) showed that mixing leads to increased skin damage; the greater the degree of damage the higher the concentrations of cortisol, glucose, and lactate in blood collected from pigs at slaughter.

CONCLUSIONS

Welfare aspects of the transport of sheep are different in many ways from those of the transport of pigs. This is partly due to differences in the husbandry and marketing of the two species and partly due to differences in their biology. It is very important that legislation and welfare codes be devised with these differences in mind.

At least in the United Kingdom, slaughter pigs tend to travel short distances, direct from farm to abattoir. Slaughter sheep often travel very long distances from farm to abattoir and may pass through markets and dealers’ premises.

For pigs, links between aspects of meat quality and conditions of handling and transport are either known or strongly suspected, but for sheep, such links are more tenuous. Likewise, some genotypes of pigs are known or suspected to be more sensitive to these conditions; this has not been shown in sheep and is unlikely to be a major problem. Experiences associated with loading appear to be stressful, but, particularly for sheep, it is not yet clear which aspects are causing the problem. The welfare insult caused by the mixing of unacquainted pigs is well known, but for sheep this insult is probably trivial.

It seems clear that pigs should have enough space to lie down, particularly during longer journeys. This is not so clear for sheep. It is possible under some circumstances (such as when sheep have just been through an arduous and tiring experience such as marketing or an earlier journey) that there should be space for lying, while under other circumstances (possibly when they have just been gathered from fields), it may be better to pack them more tightly. Lambs may differ from adult sheep in this respect.

Future research on this subject probably needs to be directed along very different lines in the two species. In pigs, better understanding of physiological processes such as travel sickness and dehydration are required. Precise studies of journey
conditions and physiological and behavioral responses to them can be made with special reference to genotype. In sheep the relative contributions of different stressors commonly experienced in the period leading up to transport (e.g., weaning, shearing, handling, marketing) must be quantified. In both species, it may be useful to adopt a problem-solving approach, answering questions like “If slaughter lambs are to undergo a journey of 24 hours, what conditions, before and during the journey, must be met to ensure satisfactory welfare?” Legislation and welfare codes in this area of public interest must be based on scientific understanding.

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