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A review of welfare in cattle, sheep and pig lairages, with emphasis on stocking rates, ventilation and noise

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Abstract

Appropriate space allowances for animals are yet to be specifically determined for lairage. Space allowances that may be suitable for animals in lairage are suggested, based on reviewed studies of animals in transport, lairage and on farm. The longer animals are in lairage the more space they require, in order to be able to get up and lie down and lie undisturbed by congeners. Little work has been done on air quality and air flow characteristics in lairages. The range of ventilation must be sufficient to control levels of toxic or irritant gases such as carbon dioxide and ammonia and to remove excess heat and humidity; the latter being particularly relevant for pig lairages in hot weather. Intensities of sound measured in lairages often exceed 85 dB and there is evidence to suggest that such levels can be stressful especially for pigs; and human shouting appears particularly aversive to animals. Cattle vocalise in response to painful stimuli and to convey information to conspecifics that may be related to fear and distress. There is limited evidence that sheep adapt to continuous sound, provided it is not too loud, but respond to intermittent sounds such as gates banging and human shouting. Vocal communication between sheep may be less important than that between cattle and pigs. Levels of vocalisation are potential indices of animal welfare. Animals' prior experiences and factors such as sex, group size and constitution, pen design, and climatic or environmental conditions affect their welfare and responses to conditions in lairage.

Keywords: *animal welfare, cattle, lairage, noise, pigs, sheep*

Introduction

Lairages perform several roles (Warriss *et al* 1992). They provide a point for ante mortem inspection and a reservoir of animals in order that the slaughter line is able to run at a constant, efficient rate. They provide an opportunity for animals to dry off should they arrive wet prior to slaughter. They are thought to promote welfare as they allow animals to rest and thereby recover from the stresses of handling and transport from farm or market. This latter role is dependent upon conditions in the lairage being conducive to rest and must, therefore, be as stress-free as possible. There are a number of factors that can contribute to this: animals should have enough space; ventilation in the lairage should be of an adequate standard and the environment should be reasonably quiet. This review focuses on these three factors, all of which were highlighted by the Farm Animal Welfare Council as of particular importance for the welfare of farmed animals prior to slaughter (FAWC 2003).

Stocking density

The terminology that's used to express the relationship between animals and space can often be imprecise. The term, 'stocking density' should be used to express the weight of the animal per unit floor area (eg kg m^{-2}) but is often used in place of 'stocking rate', which describes the number of animals per unit floor area (eg head m^{-2}). In turn, 'stocking rate' may also be used to describe the inverse which, correctly, is the 'space allowance': the floor area allocated per animal (eg m^2 per head). In this review I have tended to use the terminology of each cited reference, provided this is clarified by the units used; otherwise I have used the terms as defined above.

Overstocking may occur when lairage capacity has not been increased in line with a general trend towards increased throughput (Warriss 1994). High pen stocking rates can lead to heat stress in hot weather and prevent animals from resting owing to interference from their congeners. Animals penned at high stocking densities may not only suffer physical restriction from water but access may also be limited through social (dominance) behaviour. Stocking density cannot be considered in isolation; other important factors influencing both welfare and animals' responses to different stocking densities include: group size and sex, group constitution (of which the most important factor is whether the other animals are familiar or unfamiliar) pen design and climatic or environmental conditions. In addition, animals' space requirements will change over time (FAWC 2003, paragraph 46). Reflecting this need, FAWC

(2003) and Weeks *et al* (2008a) noted that several UK operators specify two stocking rates: one for short daytime lairage and one providing a more generous allowance for overnight lairage. To ensure acceptable levels of welfare, animals are required to have sufficient space, at least, to stand up, lie down and turn without difficulty, although higher stocking rates that would preclude these basic actions may be acceptable for short periods (FAWC 2003, paragraph 78). Unless otherwise stated, most recommendations for stocking rates in the literature reviewed below are based on such physical requirements of animals.

Cattle

Fear in cattle may contribute significantly to the establishment of dominance. In an exchange between two animals where one is clearly larger, healthier, stronger and older, it may take no more than a movement, gesture or threat to make the smaller animal submit or yield space (Albright & Arave 1997). An aggressive bull will turn his body perpendicular to a challenger to display his full height and length and, if challenged, will display aggression by bunting or striking with his head (Houpt 1998). Pen shape is of particular importance in bulls with aggression being reduced in long, narrow pens in which each bull can 'defend' a line of fence, compared to squarer pens of the same area. FAWC (2003, paragraph 46) recommend, in the promotion of welfare, that groups of beef bulls are slaughtered on arrival to limit stress from competitive aggression. In UK lairages, cattle are invariably kept in the groups in which they arrive, thus those from farms could be in the company of familiar conspecifics whereas cattle sourced from markets will tend to be mixed prior to transport. Lawrence (1994) recommends group sizes on farm of no more than 20 cattle and states that in groups of 40 or more, dominance hierarchies are unstable, particularly in groups of young bulls. Jarvis *et al* (1996) recorded group sizes in lairage from 1–27 with a median of 8 and Weeks *et al* (2008a) found a similar range from 1–34, also with a median of 8.

There appears to be little information on space allowances for cattle in lairage. A suitable recommendation for overnight lairage might be equivalent to that for the bedded area of cattle housing which increases with liveweight from 2.6 m^2 for 400 kg animals to 3.6 m^2 for cattle of 700 kg (British Standard 5502 1990). There are difficulties associated with predicting space allowances for cattle due to variable and unknown marketing weights (Scientific Committee on Animal Health and Animal Welfare [SCAHAW] 2002). This review noted that standing and lying require approximately the same floor area although the transition between the states (changes in posture such as getting up or lying down) requires additional space. Randall (1993) suggested that the formula $A = 0.021\ W^{0.67}$ m^2 (where A is space allowance in m^2 and W is the liveweight of the animal in kg) be used to calculate space allowances for cattle transported for up to 5 h. This might be useful for calculating minimum space allowances for short-term lairage (a 400 kg animal would have 1.2 m^2 and a 700 kg animal 1.7 m^2 on this basis). A recent survey of UK lairages noted that cattle space allowances, of cattle in randomly selected pens, varied from 1.3 to 19.8 m^2 per animal with an overnight median of 3.0 m^2 per head (Weeks *et al* 2008a). Studies of beef cattle on farm (eg Gupta *et al* 2007; Gygax *et al* 2007) have shown no disadvantages to welfare of increased space allowances. They noted potentially improved growth, health and cleanliness, reduced social stress and increased behavioural repertoire, including more lying. There is need for further work to assess cattle welfare and responses to lairage at different space allowances: relating these to group size and composition (sex, age, familiarity), pen shape and previous journey duration. It is a possibility, in particular regarding bulls, that space allowances for cattle in stable social groups on farm are not appropriate in lairage.

Sheep

In general, sheep are not mixed in lairage, which may be beneficial for welfare as, irrespective of breed, flocks of sheep drawn from different sources do not readily integrate into a socially homogeneous group (Winfield *et al* 1981) and pre-pubertal lambs tend to associate with flock-mates when mixed, with no differences in behaviour at high (1.0 m^2 per lamb) or low (0.3 m^2 per lamb) space allowances (Ruiz-de-la-Torre & Manteca 1999). As with other species, more work has been done on the conditions and welfare consequences of transport (as reviewed by Knowles 1998) than on lairage. Space allowances that make it possible for sheep to lie down in transit are approximately 0.25–0.27 m^2 per sheep (Cockram *et al* 1996; Kent 1997) whereas observations of lairage by Kim *et al* (1994) estimated 1 m^2 per sheep was required before most animals lay down. This is greater than the 0.56 m^2 per sheep in lairage recommended by the Meat and Livestock Commission (1974). For comparison, the recommended floor space allowance for a 32 kg hog on a farm varies from an average of 0.6 m^2 on slats to 0.8 m^2 on straw (Loynes 1983) and for lambs up to 12 months old from 0.75–0.9 m^2 per sheep (Defra 2003b). Again, both such space guidelines could be reasonably used for animals laired for a few hours but at least 0.9 m^2 per sheep are needed for overnight lairage.

For sheep in overnight lairage, a significantly positive correlation was found between increased space allowance and the likelihood that over two-thirds of the group was observed lying resting (Kim *et al* 1994). Median group size was 37 (range 2–93) with most sheep or lambs stocked at 0.5 to 2.0 m^2 per animal, although there was one instance of over 5 m^2 per sheep. A recent UK survey (Weeks *et al* 2008a) of 11 sheep lairages found median group size was 48 (range 7–455). Kim *et al* (1994) concluded that more work would need to be done on the influence of pen shape and space allowance on the lying behaviour of sheep in lairage. Under experimental conditions, Boe *et al* (2006) found that small groups of 4 sheep lay for slightly longer in deep rather than wide pens and that reducing floor space from 1.0 to 0.5 m^2 per sheep significantly reduced synchrony of lying as well as total lying time with a large increase in the number of displacements. The latter point may be especially relevant in lairages, where animals should be able to rest undisturbed. In terms of behaviour in lairage, Kim *et al* (1994) observed significantly more movement in small groups of sheep kept at high space allowance than in larger groups of sheep with lower space allowance. At higher stocking rates sheep would occasionally walk over conspecifics that were lying and it was also noted that these sheep showed an insignificant reduced tendency to show aggression or groom than those individuals with more space. Kim *et al* (1994) noted that sheep that were tightly stocked at under 0.5 m^2 per animal appeared to react less to humans in the passageway than those stocked less tightly, but at low space allowances sheep are less likely to show overt responses.

It is not easy to estimate stocking density. Warriss *et al* (2003) found girth measurements to be the most reliable method of estimating liveweight followed by a head count, but this is unlikely to be feasible for the commercial lairage situation. When standing and crowded together, a group of sheep may appear to have ample pen space as their fleeces are compressed, yet there may be insufficient space for all of them to lie without touching one another (SN Brown personal observation 2006). For this reason, for sheep, stocking rates may be more relevant than stocking densities based on weight. Knowles *et al* (1998) recommended stocking densities should be defined in terms of m^2 per 100 kg rather than m^2 per animal but this requires knowledge of the liveweight. A risk of excessive stocking density is heat stress which has been shown to limit sheeps' ability to dissipate heat while also increasing heat exchange between individuals during transport (Knowles *et al* 1998), and this can apply in lairage. Thus, particularly where sheep have been in transit for long periods, when lairage time is prolonged, when their fleece is thick and in warm or hot conditions, space allowances should be generous. The literature reviewed above indicates this should be a minimum of 0.9 m^2 per head but, as with cattle, responses (including lying behaviour) of different categories of sheep to space allowances, group size and pen shape should be measured in future research before specific recommendations are made.

Pigs

Of the three red-meat species considered here, pigs are by nature the most aggressive and tend to form dominance hierarchies. When a number of unacquainted pigs are mixed for the first time, they fight to establish a dominance hierarchy, usually of a simple linear type. The fighting behaviour is generally mouth-to-neck attacks with strong thrusts sideways and upwards (McBride *et al* 1964). Skin damage in slaughter pigs is significantly greater cranially (Geverink *et al* 1996). The establishment of the hierarchy occurs within 24 h of mixing but the level of aggression drops dramatically after approximately one hour (Symoens & van den Brande 1969). On farm, it has been found that instability within the dominance hierarchy is increased with stocking density thereby increasing stress and aggression (Turner *et al* 2000). The relevance of this to the transient conditions in lairage is not known. The behaviour of pigs in lairage can vary with duration of transit and length of time of feed withdrawal (Brown *et al* 1999a, b) as well as with sex and genotype (Warriss 2003). Studies of aggression in lairage (Moss 1978; Geverink *et al* 1996; Fraquenza *et al* 1998) show that most fighting takes 10 min to get going and occurs, generally, within the first 30–60 min. There only tends to be a few occurrences thereafter although, in larger groups, sporadic fighting can continue for longer. Brown *et al* (1999a) observed that pigs which had been deprived of food for up to 18 h showed a peak in fighting behaviour at between 40–60 min. A greater proportion of the most feed-deprived pigs fought, and fighting continued for longer compared with those that had fed within an hour before arrival in lairage, with variation in aggression levels and duration between farms of origin. For this study, authors did not record group size or stocking rate but it was noted that pigs transported with full stomachs could become travel sick.

Moss (1978) recorded more intense fighting in small groups of ten pigs with greater space allowance (0.85 m^2 per pig) than in groups of 20 pigs stocked at 0.26 m^2 per pig. Rabaste *et al* (2007) observed that pigs kept at the same space allowance of 0.59 m^2 per 108 kg pig in 'large' (30 pigs) groups in lairage fought for about 10% of the time; ten times more ($P < 0.001$) than those in 'small' groups of 10 pigs which were seen to lie more ($P < 0.05$). In five Dutch slaughterhouses, skin damage resulting from fighting in larger groups of pigs (mean group size 50 pigs, range 27–90) was significantly associated with increased time in the lairage and with greater space allowances (in the range 0.37 to 1.0 m^2 per pig) (Geverink *et al* 1996). For comparison, minimum recommended space allowances for pigs on farm are 0.66 m^2 per 100 kg pig on fully-slatted floors (Smith 1994) with similar space suggested in the UK codes of recommendation for pigs between 85 and 110 kg (Defra 2003a). This could, therefore, be an appropriate space allowance for pigs laired for several hours or overnight.

In order to minimise fighting which causes stress, physical damage and reduced meat quality, it is clearly ideal to avoid mixing unacquainted pigs in lairage pens. (Warriss 1996). If the mixing of strangers cannot be avoided, group size should possibly fall under the 20–30 mark which is an accepted estimate of the numbers recognisable by individual pigs (Fraser & Broom 1998). In Denmark, it is considered best practice to maintain pigs in their rearing groups of 15 from farm through to slaughter (Barton-Gade *et al* 1993). Schmolke *et al* (2003) found no difference in performance or tail-biting behaviour, on-farm, in grower/finisher pigs stocked at 0.76 m^2 per pig and kept in groups of 10, 20, 40 or 80 and also noted no evidence of sub-grouping in the largest group size. They did not, however, comment on levels of agonistic behaviour. Grandin (1990) indicates that subordinate pigs have greater opportunity to escape from the most aggressive pigs when group size is large (around 200 animals). It is a common commercial practice to mix large groups of unacquainted pigs together in lairage pens (Rabaste *et al* 2007). When unfamiliar pigs are mixed there can be substantial differences in the manner of agonistic encounters and resultant physical and physiological damage between individual pigs or groups of pigs (Moss 1978; Geverink *et al* 1996), which may be due in part to the length of fast (Brown *et al* 1999a). Recent measurements in 12 UK lairages found that typical group sizes were between 21 and 60 pigs per pen (maximum 88) and space allowance was in the range 0.33–2.75 with a median of 0.59 m^2 per 90–100 kg pig (Weeks *et al* 2008a).

The adverse consequences of fighting may affect pigs in neighbouring pens in lairage which, at the very least, will be disturbed by loud vocalisations accompanying fighting. In order to reduce the amount of time spent fighting, it would be logical to decrease the time spent in lairage to a minimal period. Indeed, this was suggested, along with reduced stocking density, by Geverink *et al* (1996) for the Dutch abattoirs they surveyed. However, longer periods may, in some instances, be beneficial for overall welfare as pigs seem able to recover from many stressors, including fighting and, as such, a lairage time of 2–4 h is often recommended (Warriss 2003). Warriss *et al* (1995) found plasma cortisol levels were significantly lower in pigs that had rested in lairage for 3 h than in those slaughtered shortly after transport, irrespective of whether they had been mixed in lairage or not.

The reduced carcase quality that results from fighting may be used as a retrospective indicator of welfare. Poor meat quality such as pale, soft exudative (PSE) meat relates to the recent ante-mortem welfare of pigs and can be indicative of high levels of stress in lairage as well as during transport, whereas dry, firm, dark (DFD) meat is often associated with more prolonged stress and exhaustion (Tarrant 1993). Fabrega *et al* (2007) found lower welfare to be significantly associated with DFD meat (odds ratio: 2.25) using a questionnaire-based 'welfare index'. Meat quality problems usually result from a combination of stressors and therefore do not correlate directly with stocking density. For example, the risk of PSE meat decreased with increased stocking density for short transit times; yet increased with increased stocking density (up to 0.25 m^2 per 100 kg pig) when transportation time was over 3 h (Guardia *et al* 2004). In this survey, which encompassed five Spanish abattoirs, the risk of PSE also increased in summer, indicating that high stocking density had a likely association with heat stress in the transported pigs. The authors also suggested that pigs tend to lie down after 2–3 h in transit, having adapted to their new environment, and the 'low' stocking density (0.5 m^2 per 100 kg pig) would enable them to do so. Observations by Kim *et al* (2004) support this, with a higher percentage of pigs lying during transport at 'lower' (0.39 m^2 per 100 kg pig) than at 'medium' (0.35 m^2 per 100 kg pig) or 'high' (0.31 m^2 per 100 kg pig) stocking density. They also reported that plasma concentrations of glucose, creatine kinase and lactate dehydrogenase returned to resting levels after 2 h in lairage and, further, that the incidence of PSE was greatest for groups of pigs transported at high stocking densities. It should be noted that the stocking densities used in these two studies (Guardia *et al* [2004] and Kim *et al* [2004]) were high relative to the 0.425 m^2 per 100 kg pig specified by EU Council Regulation (EC No 1/2005) on protection of animals during transport and related operations, although the high (0.31 m^2 per 100 kg pig) rate is used commercially. Studies by Lambooy *et al* (1985) found that pigs were quicker to lie down during transportation when stocked at 0.66 m^2 per pig and that at 0.39 m^2 resting was disturbed because not all pigs could lie down at once on the transporter.

For UK abattoirs, Warriss *et al* (1998) suggest around 3 h should suffice for pigs to recover from the stressful effects of transportation and reduce the occurrence of PSE meat. However, the study in Spanish abattoirs where mortality is relatively high, indicated no reduction in PSE meat with time in lairage and a slightly higher risk of PSE meat for genetically-susceptible strains with increased time in lairage (Guardia *et al* 2004). Potential stressors, such as stocking density, group size and composition and aspects of the thermal environment were not measured in this study, however, the authors did suggest that more aggressive males were more likely to produce PSE meat. Experimental work by Santos *et al* (1997), in combinations of temperature and relative humidities (RH) and either short (30 min) or long (2–3 h) periods in lairage, found that the long resting period reduced the incidence of PSE/DFD with the exception of the hottest and most humid treatment (35°C and 85% RH). In this trial, pigs were stocked at approximately 0.55 m^2 per 100 kg pig. These results were broadly confirmed by other experiments in controlled-environment lairage by Fraqueza *et al* (1998), who found no benefit to pig welfare of 3 h in lairage compared with 30 min when temperatures were 35°C and 85% RH. They also found that only around 7% of the newly-mixed pigs stocked at 0.66 m^2 per pig in groups of 30 fought, and 95% were lying down after 2 h in lairage. Despite this, skin damage was greater after longer lairage. More pigs lay down quicker at 35°C than at 20°C, but they appeared to fight more intensely at the higher temperature which could, in part, explain the higher incidence of PSE meat after 3 h lairage at 35°C.

Several studies have measured a number of aspects of pig welfare during transportation (reviewed by Lambooij 2000) including space allowances (Warriss 1998). There is less information about welfare in lairage (reviewed by Warriss 2003). In particular, there is a pressing need for stocking density to be considered in a multifactorial approach to pig welfare in lairage. Relevant factors would include genotype, group size, sex and age, temperature, humidity, air movement, pen shape, flooring as well as transit time, time in lairage, behaviour, physiology and meat quality. Ideally all factors should be monitored for the same group of pigs from farm through to slaughter.

It is impossible to evaluate the effect of stocking density on welfare, in isolation. For example, lower stocking densities enable unfamiliar pigs to fight more intensely but, at the same time, may allow subordinate pigs the opportunity to escape from dominant ones and, after a settling time, provide sufficient space for all pigs to lie and rest.

Conversely, in winter, low stocking density in poorly insulated and open lairages is likely to lead to cold stress. Group size and pen shape are highly likely to be important co-factors. At high stocking density, in the very long, narrow pens commonly found in lairages, pigs are likely to mix with only a few conspecifics in proximity and not to move around the whole pen. Thus, their social behaviour could be more akin to that of a smaller group. If stocking density were lower, however, aggression could increase not only due to increased space allowance, but also because of the opportunity to interact with more individuals. Both practical experience and experimental evidence shows an increase in heat stress at high temperatures, maximised at high humidities and at high stocking densities. A further factor influencing stress in lairage is the genetic susceptibility of the pigs, which varies between strains. A positive response to the halothane test indicates susceptibility to stress, and one study has found that highly stress-susceptible genotypes benefited from longer times (up to 5 h) in lairage to recover from transport stress (De Smet *et al* 1996).

Until further information becomes available, the guidance provided in the review by SCAHAW (2002) could be used in lairage, subject to more generous allowances being used when air temperatures and humidities are high. The SCAHAW guidance is: "Where pigs must be held for a period before loading onto a transport vehicle or after unloading, the space allowance provided should be according to the following formulae:

For 3 h or more: $A = 0.03W^{0.67}$ m^2; for 30 min to 3 h: $A = 0.026W^{0.67}$ m^2 and for up to 30 min: $A = 0.0192W^{0.67}$ m^2 whereby A = area in m^2 per pig and W is weight of pig in kg)."

For 100 kg pigs, this works out as 0.42 m^2 per pig for short lairage, 0.57 m^2 per pig for lairage up to 3 h and 0.66 m^2 per pig for lairage over 3 h, ie overnight.

Table 1 summarises possible space allowances for cattle, sheep and pigs in lairage, based on current knowledge.

Table 1 Suggested space allowances for short and long lairage which may need to be adjusted for particular circumstances and increased in hot weather.

Space allowance (m^2 per head)	Cattle (700 kg)	Sheep/lambs ($\leq$ 1 year old)	Pigs (90–100 kg)
Short lairage (< 3 h)	1.7	0.56	0.42
Long lairage (> 3 h)	3.6	0.8 to 1.0	0.66

Ventilation and air quality

Ventilation needs to be sufficient, at the very least, to prevent build up of carbon dioxide and noxious gases such as ammonia. Inadequate ventilation is indicated by low air movement at animal level and by high levels of pollutant gases, such as ammonia which can be measured relatively easily. Indeed, the smell of ammonia is sufficient to indicate that minimum ventilation rates are not being achieved. Health and Safety maximum permitted exposure for humans is 25 ppm in the UK and this is a guideline maximum for livestock. Maximum ventilation is needed to remove excess heat and moisture, particularly in hot weather. An easily measured indication of sufficient ventilation in hot weather is the temperature difference between the inside of the building and the outside which, in general, should be less than 3°C (Seedorf *et al* 1998). Ventilation needs, therefore, to be adjustable in order to accommodate different weather and stocking conditions within the lairage. Observation of the animals allows an animal-based assessment of welfare, whereby panting in ruminants and wallowing/moisture-seeking in pigs may be associated with the animals overheating; and huddling or shivering an indication that they are too cold. However, ruminants are very cold tolerant and unlikely to offer any visual clues of ventilation too low to remove noxious gases in winter.

Lairages face the unique problem of encountering unpredictable and frequently varying numbers of animal and yet, for practical reasons (such as ease of animal movement), are seldom environmentally-controlled to take this into account. Lairages are rarely designed for good control of ventilation, having poorly-defined air inlets and outlets and often relying on natural ventilation or fan-assisted natural ventilation. It is technically very difficult to measure the ventilation rate in buildings that have large, open sides as the more accurate methods rely upon the use of tracer gases that tend to disperse unevenly and too quickly in such conditions. We have found no reported measurements of ventilation rates or characteristics in lairages. Some lairage designers and operators appear to take the pragmatic view that an animal's time in lairage is so short that it suffices to protect it from the extremes of climate. However, more careful siting and design could inexpensively improve thermal comfort and air quality for both humans and animals. Principles of ventilation control, including the relative siting of air inlets and outlets, are given by Randall and Boon (1994).

Cattle and sheep

Ruminants have a wide range of thermoneutrality from about 10 to 30°C (Webster 1983) and the rumen maintains a flow of nutrients and energy to the animal even after a short period of feed withdrawal. They are likely, therefore, to be able to tolerate temperatures in most lairages perfectly adequately. At high stocking densities, in particular, good ventilation is needed to remove noxious gases at all air temperatures and this is likely to need to be in excess of the minimum 0.35 m^3 h^{-1} kg^{-1} liveweight suggested by Charles (1994), particularly where slatted floors are used. Weeks *et al* (2008a) found in some lairages the mean daytime ammonia levels in summer were as high as 18 ppm for cattle and 22 ppm for sheep, with individual readings well in excess of the recommended maximum of 25 ppm (Groot Koerkamp *et al* 1998) thereby indicating that ventilation rates were insufficient. There appears to be no knowledge of the relative aversiveness of different concentrations of ammonia gas in the air to cattle and sheep, however, to promote welfare the levels of this known irritant and noxious gas should be kept as low as possible (under 3 ppm, approximately the threshold of detection by most humans and commonly used chemical crystal detectors).

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Maximal ventilation rates in excess of 4 m^3 h^{-1} kg^{-1} may be needed, especially in hot weather and when lairages are stocked to capacity, in which case fan-assisted ventilation is likely to be needed. Air movement should be easily detected at animal height and, for comfort and good welfare, resting animals should not be observed panting.

Pigs

Most pigs are reared in insulated farm buildings with control of temperature and ventilation using fans. This is aimed at conserving feed by keeping the pigs in or close to their thermoneutral (comfort) zone, which for fed pigs is approximately 20–23°C (Webster 1983). The recommended range of air temperature for 80 kg pigs in buildings is approximately 15–29°C (Wathes *et al* 1983). Slaughter pigs, which have not been recently fed, may find it harder to keep warm, although there is no evidence that during time in lairage they suffer cold stress, where the body temperature drops. Some older pig lairages may provide insufficient protection from chilling winds and, in cool weather, pigs have been observed shivering (Knowles *et al* 1998). For welfare reasons these authors recommended that pigs should not be continuously showered when ambient temperatures are below 5°C. Brent (1986) states that air movement above 0.2 m s^{-1} will cause discomfort to pigs, particularly when they are underfed and air temperatures are below their lower critical temperature. Pigs in lairage are generally fasted, however the lower critical temperature is lower with high stocking density and if straw bedding is provided.

A potential problem in most pig lairages during summer months is the high humidity produced by the use of misting sprays, designed to cool and clean animals prior to slaughter. In combination with high temperature, high humidity causes heat stress (Santos *et al* 1997). Warriss (2003) notes that it is important for lairage ventilation to be sufficient to prevent high humidities that reduce heat loss by evaporation from pigs at high ambient temperatures. In Brazil, Perdomo *et al* (1999) noted reduced on-farm performance and feed intake of sows in hot weather (> 22°C), particularly when air flow dropped below 0.2 m s^{-1} under natural ventilation. They concluded that mechanical ventilation and faster airflow was necessary for pigs in hot weather but that natural ventilation sufficed in cooler conditions. Weeks *et al* (2008a) measured air speeds proximal to pigs in lairage and found summer means of up to 0.6 m s^{-1} with means in winter below 0.2 m s^{-1}. The suggested range of ventilation for 100 kg pigs is 1.65 to 16.5 m^3 h^{-1} in normal UK animal housing (calculated from Charles 1994; Table 1). However, this lower rate may be insufficient to maintain carbon dioxide levels below the 0.3% recommended by Brent (1986), who suggests 6.6 m^3 h^{-1} pig^{-1}. Similarly, maximum ventilation rates may need to be of the order of 135 m^3 h^{-1} pig^{-1} to maintain a temperature lift of no more than 3°C over ambient (Brent 1986).

In an experimental-choice experiment, pigs significantly preferred to be in chambers free from atmospheric ammonia, and proportionately reduced their visit time and duration to chambers with concentrations of ammonia of 10, 20 and 40 ppm (Wathes *et al* 2002). However, the higher concentrations of ammonia were not instantly aversive and animals voluntarily spent up to 60 min prior to withdrawing. Thus, exposure to moderate (eg 10 ppm) levels of ammonia in lairage for short periods of time (< 1 h) in lairage might not be aversive to pigs. Nonetheless, as for ruminants, levels should be kept to a minimum to promote good welfare.

Noise

Lairages can be relatively noisy, especially when compared with most farm environments. This is due partly to the fact that animals are being continually moved in and out, with the necessary opening and closing of gates and doors. However, it is also because they tend to be situated adjacent to two major sources of noise: one is the unloading area, where vehicles manoeuvring, being washed out and being unloaded are all noisy operations and the other is the abattoir itself, which is usually very noisy because of the operation of the equipment, radios and personnel. Moreover, for the purposes of hygiene, surfaces are hard, reflecting and amplifying rather than absorbing sound. A further source of noise is from animal vocalisations which, especially in pigs, may be an indication of fear and stress.

Livestock generally possess more acute hearing than humans and are, thus, sensitive to both environmental and animal sounds inaudible to humans. The extended frequency range probably evolved to enable them to detect and monitor the activity of predators at a considerable distance. Delpietro (1989) reported cases of cattle showing defensive responses to the screams of vampire bats. Thus, livestock may be especially alarmed by or fearful of very high pitched sounds (above about 6–8 kHz).

Typical average levels of noise measured in animal housing on farms in Sweden by Algers *et al* (1978b) were 58.6 dB(A) for fattening pigs and 57.3 dB(A) for cows. They did not measure noise exposure for beef cattle or sheep but stated that typical measures for grazing cattle 'in calm nature' were 35 dB(A). The authors proposed that a sound equivalent level over 24 h was set at 45 dB(A). Experiments on noise with lambs by Ames and Arehart (1972) indicated that prolonged exposure to loud noise (eg 100 dB for 8 h) increased their respiration rate. Lambs not previously exposed to loud noise had elevated heart rates when exposed to 100 dB. Algers *et al* (1978a) review evidence from studies in man and other animals, such as rats, that loud noise is stressful, with short-term physiological responses but 'unknown long-term consequences'.

Characteristics of sound

In order to put some of the measurements of sound and the auditory capacities of livestock into context, some characteristics of sound and hearing in humans are briefly outlined. The frequency of sound vibrations, also known as the pitch, is measured in Hertz (Hz). The range of frequencies that the human ear can detect (auditory range) is generally within 20 Hz to 20 kHz. Humans are most sensitive to tones in the range of 500 Hz to 4 kHz which includes the range of normal speech (ie within this range we can hear quieter sounds). The ear's response to increasing

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sound intensity is a 'power of ten' or logarithmic relationship. This is one of the motivations for using the decibel scale to measure sound intensity. It is generally felt, for loudness, that the power must be increased by about a factor of ten to sound twice as loud. Sound meters and the decibel scales (dB A, B or C) have been developed to reflect the sensitivity of the human ear but are also considered applicable to animals, particularly in the frequency range of sounds likely to be generated within lairages. The threshold of hearing for (young) humans is 0 dB (at 4 kHz) and above 125 dB the sound becomes loud enough to cause pain.

Cattle

Vocalisations and hearing in cattle are important for communication and they also respond to the vocalisations of other species (Phillips 1993) as might be expected in herd animals that evolved in multi-species grazing environments and which are prey to carnivores. Cattle vocalisations generally range between 50 and 1,250 Hz (Kiley 1972). Vocalisations of newly-weaned calves with fundamental frequencies as low as 31 Hz have been recorded (Watts & Stookey 2000) and this is in the long-ranging infrasonic region used by elephants. Indeed, cattle, with an auditory range between 25 Hz and 35 kHz, can detect lower pitched sounds than other farm species and the frequency of their most acute hearing is the same as pigs at 8 kHz (Heffner & Heffner 1992).

Cattle can be calmed by playing soothing music. Dairy breeds are more sensitive to sound and touch than beef breeds (Lanier *et al* 2000). Shouting at dairy cows appears to be very aversive to them (Pajor *et al* 1999). Algers and Jensen (1991) cite that Plyashchenko and Sidorov (1984) found reduced milk yield in dairy cows exposed to 1.4 h of 80–100 dB of noise twice daily. Sounds made by humans handling cattle provoked greater reactivity and increased heart rates for these animals than equipment sounds such as gates banging (Waynert *et al* 1999). Lanier *et al* (2000) also noted that cattle appeared more stressed by intermittent loud human vocalisation, particularly when high-pitched like a child's, than by noises such as the ringing of telephones or gates slamming. Weeks *et al* (2008b) measured the latter at 75–90 (mean 84) dB(A) and noted the crush systems used to restrain cattle for ear-tag reading were a source of high intensities of sound (consistently 85–90 dB[A]).

Cattle may produce specific and more numerous vocalisations in response to painful stimuli such as hot-iron branding (Watts & Stookey 1999). Grandin (2001) recorded that cattle vocalised in response to poor handling (eg use of electric goads or prods) and to equipment problems at beef slaughter plants. She proposed the level of vocalisation as an index of cattle welfare in the abattoir. Thus, evidence exists that cattle vocalisation may convey specific information related to fear and distress to conspecifics in lairage which could affect their ability to rest even more than volume alone. Weeks *et al* (2008b) recorded the mean levels of vocalisations from cattle in the range 80–90 dB(A). Both qualitative and quantitative aspects of noise should perhaps be considered for a thorough evaluation of its impact on welfare in lairage.

Sheep

Sheep appear to adapt to increased noise levels, particularly when these are relatively continuous, such as the noise of transport vehicles at around 60–90 dB(A), although they may show an initial rise in heart rate (Hall *et al* 1998). Kim *et al* (1994) noted that sheep in lairage appeared more responsive to human vocalisation and to mechanical noise such as metal banging and hosing than to noises of animal origin (eg pig or cattle vocalisation or cattle fighting/mounting) but they did not record noise levels. Weeks *et al* (2008b) found mean sound levels from clanging gates and other fittings in 11 sheep lairages to be 76 dB(A) and they recorded sheep vocalisations at around 70 dB(A).

The auditory range of sheep is 125 Hz to 40 kHz with the most sensitive frequency a little higher than cattle and pigs at 10 kHz (Heffner & Heffner 1992). Unlike cattle, sheep do not vocalise in response to painful stimuli. Apart from vocalisation between ewes and their lambs, vocal communication between sheep has not been studied in detail.

Pigs

Auditory stimuli are used extensively by pigs as a means of communication in all social activities (Gonyou 2001). Alarm or aversive stimuli are transmitted to conspecifics by auditory cues as well as via pheromones (Vieuille-Thomas & Signoret 1992). For example, Weary *et al* (1998) suggested that high-pitched (above 1 kHz) vocalisations by piglets were indicative of pain during castration. The heart rate of piglets increased more in response to high than to low frequency (pitched) sounds and when the high-pitched sounds were also loud, the piglets moved away (Talling *et al* 1996). In a further experiment, it was found that intermittent, sudden sounds provoked greater responses in pigs than constant sounds (Talling *et al* 1998a).

The auditory range of pigs is between 55 Hz and 40 kHz and their sense of hearing is more sensitive in the range 500 Hz to 16 kHz (particularly acute around 8 kHz [Heffner & Heffner 1992]). Typically, pigs are exposed to noise levels of around 73 dB on farms in the range 20 Hz to 6.3 kHz, and to levels on transport lorries of 91 dB at below 16 kHz (Talling *et al* 1998b). In four lairages these authors measured noise levels between 76 and 86 dB, with up to 97 dB in the pre-stun pens. The movement of machinery as well as pig vocalisations were found to be a major source of noise and it was concluded that the sound levels and types of sound pigs were exposed to in transit and in lairage were likely to be aversive, and should therefore be regulated to improve welfare (Talling *et al* 1998a). Rabaste *et al* (2007) recently measured sound levels in Canadian lairages in the range 82–108 dB. This is in accordance with levels reported by FAWC (2003), indicating that noise levels recorded in pig lairages varied between 74–90 dB (A) with levels in handling systems rising as high as 120 dB(A) which is approaching the pain threshold for humans. The FAWC report did not provide details of the source or frequency of these sounds. Weeks *et al* (2008b) measured the sound from gates clanging at a consistent 85 dB(A) and found the principal source of loud noise in spot measurements to be pig vocalisations which averaged 80–103 dB(A).

In an experimental situation, Geverink *et al* (1998b) exposed pigs to recorded lairage machinery or pig vocalisations, with white noise or no sound as controls, and found no significant differences in salivary cortisol or heart rate response between the sounds; each played at 85 dB(A) for 10 min. However, these recordings, at a constant level of sound, may not reflect the real-life variable noises pigs are exposed to in lairage. Similarly, Algers and Jensen (1985, 1991) experimentally exposed nursing sows and piglets to recordings of fan noise at 85 dB(A) and found significantly decreased massaging of the udder and hence reduced milk production. In another study, Kanitz *et al* (2005) exposed pigs to daily or three-times weekly broad-band noise at 90 dB for two hours. This caused both short-term adrenocortical and long-term stress effects which adds to the evidence that the noise levels in lairages, which are often at this level, are likely to be stressful to pigs.

For pigs, the source and frequency (or pitch) of sounds and whether they are intermittent or continuous, appears to have implications for welfare. A system for automatically detecting and recording pigs' stress vocalisations, specifically, has been developed (Schon *et al* 2004) and levels of these could provide a useful index of welfare in the lairage environment.

Animal welfare implications

For all species, both the qualitative and the quantitative aspects of noise should be considered for a thorough evaluation of impacts on welfare. In particular, the frequency distributions of potentially aversive sounds need to be measured. Both high stocking rates and mixing of animals should be avoided in order to minimise social stress, fighting, disturbed rest and to improve access to water. More research is needed to establish the aversiveness of lairage conditions to animals with varied history. The evidence to date suggests that for optimum welfare, cattle and sheep should be slaughtered without delay and pigs after a short period in lairage. However, there is no current evidence that longer periods in lairage are detrimental to welfare if quiet, spacious, well-bedded, well-ventilated and thermally-comfortable conditions are provided together with easy access to clean water (and feed where appropriate).

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References

Albright JL and Arave CW 1997 *The Behaviour of Cattle*. CAB International: Wallingford, UK

Algers B, Ekesbo I and Stromberg S 1978a Impact of continuous noise on animal health. *Acta Veterinaria Scandinavica S67*: 5-26

Algers B, Ekesbo I and Stromberg S 1978b Noise measurements in farm animal environments. *Acta Veterinaria Scandinavica S68*: 3-19

Algers B and Jensen P 1985 Communication during suckling in the domestic pig; effects of continuous noise. *Applied Animal Behaviour Science 14*: 49-61

Algers B and Jensen P 1991 Teat stimulation and milk production during early lactation in sows: effects of continuous noise. *Canadian Journal of Animal Science 71*: 51-60

Ames DR and Arehart LA 1972 Physiological responses of lambs to auditory stimuli. *Journal of Animal Science 34*: 994-998

Barton Gade P, Blaabjerg L and Christensen L 1993 New lairage system for slaughter pigs: effect on behaviour and slaughter characteristics. *Meat Focus International 2*: 115-118

Boe KE, Berg SN and Andersen IL 2006 Resting behaviour and displacements in ewes: effects of reduced lying space and pen shape. *Applied Animal Behaviour Science 98*: 249-259

Brent G 1986 *Housing the Pig*. Farming Press Ltd: Ipswich, UK

British Standard 5502 1990 *Buildings and Structures for Agriculture. Part 40: Code of Practice for Design and Construction of Cattle Buildings*. British Standards Institute: London, UK. In: Wathes CM and Charles DRC (eds) *Livestock Housing*. CAB International: Wallingford, UK

Brown SN, Knowles TG, Edwards JE and Warriss PD 1999a Relationship between food deprivation before transport and aggression in pigs held in lairage before slaughter. *Veterinary Record 145*: 630-634

Brown SN, Knowles TG, Edwards JE and Warriss PD 1999b Behavioural and physiological responses of pigs to being transported for up to 24 hours followed by six hours of recovery in lairage. *Veterinary Record 145*: 421-426

Charles DRC 1994 Comparative climatic requirements. In: Wathes CM and Charles DRC (eds) *Livestock Housing*. CAB International: Wallingford, UK

Cockram MS, Kent JE, Goddard PJ, Waran NK, McGilp IM, Jackson RE, Muwanga GM and Prytherch S 1996 Effect of space allowance during transport on the behavioural and physiological responses of lambs during and after transport. *Animal Science 62*: 461-477

Defra 2003a *Code of Recommendations for the Welfare of Livestock Sheep*. Defra Publications, Admail 6000: London SW1A 2XX, UK

Defra 2003b *Code of Recommendations for the Welfare of Livestock Pigs*. Defra Publications, Admail 6000: London SW1A 2XX, UK

Delpietro HA 1989 Case reports on defensive behaviour in equine and bovine subjects in response to vocalization of the common vampire bat (*Desmodus rotundus*). *Applied Animal Behaviour Science 22*: 377–380

De Smet SM, Pauwels H, Debie S, Demeyer DI, Calleweir J and Eeckout W 1996 Effect of halothane genotype, breed, feed withdrawal, and lairage on pork quality of Belgian slaughter pigs. *Journal of Animal Science 74*: 1854-1863

Fabrega E, Coma J, Tibau J, Manteca X and Velarde A 2007 Evaluation of parameters for monitoring welfare during transport and lairage at the abattoir in pigs. *Animal Welfare 16*: 201-204

FAWC 2003 *Report on the Welfare of Farmed Animals at Slaughter or Killing. Part 1: Red Meat Animals*. FAWC: 1A Page Street, London SW1P 4PQ, UK

Fraqueza MJ, Roseiro LC, Almeida J, Matias E, Santos C and Randall JM 1998 Effects of lairage temperature and holding time on pig behaviour and on carcass and meat quality. *Applied Animal Behaviour Science 60*: 317-330

Fraser AF and Broom DM 1998 *Farm Animal Behaviour and Welfare*. Bailliere-Tindall and Cassell: London, UK

Geverink NA, Engel B, Lambooij E and Wiegant VM 1996 Handling of slaughter pigs in lairage: behavioural and physiological effects. *Proceedings of the EU seminar New Information on Welfare and Meat Quality of Pigs as Related to Handling, Transport and Lairage Conditions* pp 207-212. June 29-30 1995, Landbauforschung, Völkenrode, Sonderheft 166, Mariensee, Germany

Geverink NA, Buhnemann A, van de Burgwal JA, Lambooij E, Blokhuis HJ and Wiegant VM 1998 Responses of slaughter pigs to transport and lairage sounds. *Physiology & Behavior 63(4)*: 667-673

Gonyou HW 2001 The social behaviour of pigs. In: Keeling LJ and Gonyou HW (eds) *Social Behaviour in Farm Animals*. CAB International: Wallingford, UK

Grandin T 1990 Design of loading facilities and holding pens. *Applied Animal Behaviour Science 28*: 187-201

Grandin T 2001 Cattle vocalisations are associated with handling and equipment problems at beef slaughter plants. *Applied Animal Behaviour Science 71*: 191-201

Groot Koerkamp PWG, Metz JHM, Uenk GH, Phillips VR, Holden MR, Sneath RW, Short JL, White RP, Hartung J, Seedorf J, Schröder M, Linkert KH, Pedersen S, Takai H, Johnsen JO and Wathes CM 1998 Concentrations and emissions of ammonia in livestock buildings in Northern Europe. *Journal of Agricultural Engineering Research 70*: 79-95

Guardia MD, Estany J, Balasasch S, Oliver MA, Gispert M and Diestre A 2004 Risk assessment of PSE condition due to preslaughter conditions and RYR1 gene in pigs. *Meat Science 67*: 471-478

Gupta S, Earley B and Crowe MA 2007 Pituitary, adrenal, immune and performance responses of mature Holstein × Friesian bulls housed on slatted floors at various space allowances. *Veterinary Journal 173*: 594-604

Gygax L, Siegwart R and Wechsler B 2007 Effects of space allowance on the behaviour and cleanliness of finishing bulls kept in pens with fully slatted rubber coated flooring. *Applied Animal behaviour Science 107*: 1-12

Hall SJG, Kirkpatrick SM, Lloyd DM and Broom DM 1998 Noise and vehicular motion as potential stressors during the transport of sheep. *Animal Science 67*: 467-473

Heffner RS and Heffner HE 1992 Auditory perception. In: Phillips C and Piggins D (eds) *Farm Animals and the Environment*. CAB International: Wallingford, UK

Houpt K 1998 *Domestic Animal Behavior for Veterinarians and Animal Scientists*. Iowa State University Press: Ames, Iowa, USA

Jarvis AM, Harrington DWJ and Cockram MS 1996 Effect of source and lairage on some behavioural and biochemical measurements of feed restriction and dehydration in cattle at a slaughterhouse. *Applied Animal Behaviour Science 50*: 83-94

Kanitz E, Otten W and Tuchscherer M 2005 Central and peripheral effects of repeated noise stress on hypothalamic-pituitary-adrenocortical axis in pigs. *Livestock Production Science 94*: 213-224

Kent JE 1997 Stress in transported sheep. *Comparative Haematology International 7*: 163-166

Kiley M 1972 The vocalizations of ungulates, their causation and function. *Zeitschrift fur Tierpsychologie 31*: 171-222

Kim FB, Jackson RE, Gordon GDH and Cockram MS 1994 Resting behaviour of sheep in a slaughterhouse lairage. *Applied Animal Behaviour Science 40*: 45-54

Kim DH, Woo JH and Lee CY 2004 Effects of stocking density and transportation time of market pigs in their behaviour, plasma concentrations of glucose and stress-associated enzymes and carcass quality. *Asian-Australasian Journal of Animal Sciences 17*: 116-121

Knowles TG 1998 A review of the road transport of slaughter sheep. *Veterinary Record 143*: 212-219

Knowles TG, Brown SN, Edwards JE and Warriss PD 1998 A minimum ambient temperature below which pigs should not be continuously showered in lairage. *Veterinary Record 143*: 575-578

Lambooij E 2000 Transport of pigs. In: Grandin T (ed) *Livestock Handling and Transport*. CAB International: Wallingford, UK

Lambooy E, Garssen GJ, Walstra P, Mateman G and Merkus GSM 1985 Transport of pigs by car for 2 days: some aspects of watering and load density. *Livestock Production Science 13*: 289-299

Lanier JL, Grandin T, Green RD, Avery D and McGee K 2000 The relationship between reaction to sudden intermittent movements and sounds and temperament. *Journal of Animal Science 78*: 1467–1474

Lawrence NG 1994 Beef Cattle Housing In: Wathes CM and Charles DRC (eds) *Livestock Housing*. CAB International: Wallingford, UK

Loynes IJ 1983 *Housing Sheep*. Farm Buildings Information Centre: Stoneleigh, UK. In: Wathes CM and Charles DRC (eds) *Livestock Housing*. CAB International: Wallingford, UK

McBride G, James JW and Hodgens N 1964 Social behaviour of domestic animals IV: Growing pigs. *Animal Production 6*: 129-139

Meat and Livestock Commission 1974 *Guidelines for Export Slaughterhouses Technical Bulletin No. 13*. Meat and Livestock Commission: Milton Keynes, UK

Moss BW 1978 Some observations on the activity and aggressive behaviour of pigs when penned prior to slaughter. *Applied Animal Ethology 4*: 323-339

Pajor EA, Rushen J and de Pasille AM 1999 Aversion learning techniques to evaluate dairy cow handling practices. *Journal of Animal Science 77(1)*: 149

Perdomo CC, Fernandes LCDO, Guidoni AL and Fialho FB 1999 Effect of natural and mechanical ventilation on performance of lactation sows. *Persquisa Agropecuaria Brasileira 34*: 691-699

Phillips CJC 1993 *Cattle Behaviour*. Farming Press Books: Ipswich, UK

Plyashchenko SI and Sidorov VT 1984 Effects of production noises on the state of health, productivity and behaviour of cows. *Soviet Agricultural Science (USA) 5*: 51-54

Rabaste C, Faucitano L, Saucier L, Mormede P, Correa JA, Giguere A and Bergeron R 2007 The effects of handling and group size on welfare of pigs in lairage and their influence on stomach weight, carcass microbial contamination and meat quality. *Canadian Journal of Meat Science 87*: 3-12

Randall JM 1993 Environmental parameters necessary to define comfort for pigs, cattle and sheep in livestock transporters. *Animal Production 57*: 299-307

Randall JM and Boon CR 1994 Ventilation and control. In: Wathes CM and Charles DRC (eds) *Livestock Housing*. CAB International: Wallingford, UK

Ruiz-de-la-Torre JL and Manteca X 1999 Behavioural effects of social mixing at different stocking densities in prepubertal lambs. *Animal Welfare 8(2)*: 117-126

Santos C, Almeida JM, Matias EC, Fraqueza MJ, Roseiro C and Sardinia L 1997 Influence of lairage environmental conditions and resting time on meat quality in pigs. *Meat Science 45*: 253-262

SCAHAW 2002 *Scientific Committee on Animal Health and Animal Welfare: The Welfare of Animals During Transport (Details for Horses, Pigs, Sheep and Cattle). European Commission, Health and Consumer Protection Directorate General.* Report adopted on 11th March 2002. Available at: http://ec.europa.eu/food/fs/sc/scah/out71_en.pdf (accessed 24/4/2008)

Schmolke SA, Li YZ and Gonyou HW 2003 Effect of group size on performance of growing-finishing pigs. *Journal of Animal Science 81*: 874-878

Schon PC, Puppe B and Manteuffel G 2004 Automated recording of stress vocalisations as a tool to document impaired welfare in pigs. *Animal Welfare 13*: 105-110

Seedorf J, Hartung J, Schröder M, Linkert KH, Pedersen S, Takai H, Johnsen JO, Metz JHM, Groot Koerkamp PWG, Uenk HG, Phillips VR, Holden MR, Sneath RW, Short JL, White RP and Wathes CM 1998 A Survey of Ventilation Rates in Livestock Buildings in Northern Europe. *Journal of Agricultural Engineering Research: 70*: 39-47

Smith AT 1994 Pig Housing. In: Wathes CM and Charles DRC (eds) *Livestock Housing*. CAB International: Wallingford, UK

Symoens J and van den Brande M 1969 Prevention and cure of aggressiveness in pigs using the sedative azaperone. *Veterinary Record 85*: 64-67

Talling JC, Waran NK and Wathes CM 1996 Behavioural and physiological responses of pigs to sound. *Applied Animal Behaviour Science 48*: 187-202

Talling JC, Waran NK, Wathes CM and Lines JA 1998a Sound avoidance by domestic pigs depends upon characteristics of the signal. *Applied Animal Behaviour Science 58*: 255-266

Talling JC, Lines JA, Wathes CM and Waran NK 1998b The acoustic environment of the domestic pig. *Journal of Agricultural Engineering Research 71*: 1-12

Tarrant PV 1993 An overview of production, slaughter and processing factors that affect pork quality: general review. In: Puolanne E and Demeyer DI (eds) *Pork Quality: Genetic and Metabolic Factors*. CAB International: Wallingford, UK

Turner SP, Ewen M, Rooke JA and Edwards SA 2000 The effect of space allowance on performance, aggression and immune competence of growing pigs housed on straw deep-litter at different group sizes. *Livestock Production Science*: *66*: 47-55

Vieuille-Thomas C and Signoret JP 1992 Pheromonal transmission of an aversive experience in domestic pigs. *Journal of Chemical Ecology 18*: 1551-1557

Warriss PD, Brown SN, Edwards JE, Anil MH and Fordham DP 1992 The time in lairage needed by pigs to recover from the stress of transport. *Veterinary Record 131*: 194-196

Warriss PD 1994 Handling pigs immediately preslaughter: practical concerns and considerations for welfare and meat quality. *Meat Focus International 3*: 167-171

Warriss PD, Brown SN, Nute GR, Knowles TG, Edwards JE, Perry AM and Johnson SP 1995 Potential interactions between the effects of preslaughter stress and postmortem electrical-stimulation of the carcass on meat quality in pigs. *Meat Science 41*: 55-68

Warriss PD 1996 The consequences of fighting between mixed groups of unfamiliar pigs before slaughter. *Meat Focus International 5*: 89-93

Warriss PD 1998 Choosing appropriate space allowances for slaughter pigs transported by road: a review. *Veterinary Record 142*: 449-454

Warriss PD, Brown SN, Edwards JE and Knowles TG 1998 Effect of lairage time on levels of stress and meat quality in pigs. *Animal Science 66*: 255-261

Warriss PD 2003 Optimal lairage times and conditions for slaughter pigs: a review. *Veterinary Record 153*: 170-176

Warriss PD, Brown SN and Knowles TG 2003 Assessment of possible methods for estimating the stocking density of sheep being carried on commercial vehicles. *Veterinary Record 150*: 233-236

Wathes CM, Jones CDM and Webster AJF 1983 Ventilation, air hygiene and animal health. *Veterinary Record 113*: 554-559

Wathes CM, Jones JB, Kristensen HH, Jones EKM and Webster AJF 2002 Aversion of pigs and domestic fowl to atmospheric ammonia. *Transactions of the ASAE 45*: 1605-1610

Watts JM and Stookey JM 1999 Effects of restraint and branding on rates and acoustic parameters of vocalization in beef cattle. *Applied Animal Behaviour Science 62*: 125-135

Watts JM and Stookey JM 2000 Vocal behaviour in cattle: the animal's commentary on its biological processes and welfare. *Applied Animal Behaviour Science 67*: 15-33

Waynert DF, Stookey JM, Swartzkopf-Genwein KS, Watts JM and Waltz CS 1999 Responses of beef cattle to noise during handling. *Applied Animal Behaviour Science 62*: 27-42

Weary DM, Braithwaite LA and Fraser D 1998 Vocal response to pain in piglets. *Applied Animal Behaviour Science 56*: 161-172

Webster AJF 1983 Nutrition and the thermal environment. In: Rook JAF and Thomas PC (eds) *Nutritional Physiology of Farm Animals*. Longman: London, UK

Weeks CA, Brown SN, Lane S, Heasman L, Benson T and Warriss PD 2008a *Lairage Report*. http://www.defra.gov.uk/science/Project_Data /DocumentLibrary/MH0132/MH1032_5725_FRA.doc

Weeks CA, Brown SN, Lane S, Heasman L, Benson T and Warriss PD 2008b Noise levels in UK cattle, sheep and pig lairages. *Submitted for publication*

Winfield CG, Syme GJ and Pearson AJ 1981 Effect of familiarity with each other and breed on the spatial behaviour of sheep in an open field. *Applied Animal Ethology 7*: 67-75