Farm Animal Transport, Welfare and Meat Quality

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Thesis (Masters)

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CONTENTS

SUMMARY

When animals are exposed to a novel situation such as transportation, they react by eliciting certain physiological and behavioural functions in order to cope with the situation. These changes can be measured to indicate how much stress the animal is suffering. Physiological stress indicators often measured in animal transport research include changes in heart rate, live-weight, cortisol levels, and blood composition including electrolytes, metabolites and enzymes (Broom and Johnson, 1993). Animal behavioural stress indicators include struggling, vocalisation, kicking or biting, hunching of the back, urination, defecation and recumbence (Broom et al. 1996; Gregory, 1998). Meat quality parameters post mortem can also help to indicate stress levels in animals (Grandin, 1990; Gregory, 1998). These include incidence of bruising and DFD in all farm animal species and PSE in pigs. Mortality is also an obvious indicator of poor welfare.

Combined aspects of transport that contribute to causing stress in livestock include loading and unloading procedures, close proximity to stock handlers, water/feed deprivation, noise, riding in a truck, mixing with other animals and being forced into unfamiliar environments. The responses of stock to these conditions will depend on the animal's genetically controlled adaptability, physical condition and its previous handling experiences (Gross and Siegel, 1993).

Factors such as the adequate preparation of animals for transport, controlled prior access to feed and water, minimal disruption to social groups, considerate animal handling skills, adequate handling and transport facilities including good ventilation in trucks, and careful driving technique are major areas that dictate the standard of animal transport. For example, considerations for pigs should include a pre-transport fasting period which balances the requirement to avoid hunger, travel sickness and deaths. Breeding and selecting for more stress-resistant genotypes of pigs can improve the welfare by reducing mortality and the metabolic consequences of transport stress.

Other factors influencing animal transport include farm size and country size. For example, livestock transport in Scandinavia involves transport vehicles travelling to more than one farm in order to fill a vehicle. In Australia often one farm pick up can fill a truck, and although the distances

may be much longer to the abattoir, it will be more direct. The market demand dictates the type of animals transported. For example the veal trade in Europe demands young live calves to be transported over long distances from northern countries which supply it to the southern countries which demand it. This trade exists in live animals rather than meat because the demanding countries further fatten and slaughter these animals specific to their needs.

The industry set up influences the standard of animal transport in different countries. For example in countries where industries are vertically integrated consisting of producer-owned slaughter plant co-operatives (Sweden and Denmark), producers are paid according to slaughter weight and lean meat percentage, therefore there is more consistent quality control measures in place. In Australia the marketing system is such that it provides no economic incentive to reduce losses.

Greater public awareness of animal welfare seems to be increasing in western countries, and as a result there is more pressure on the livestock industry to adopt better standards for the farming, handling, transport and slaughter of animals. The transport of livestock in Australia continues to be under increased scrutiny from overseas markets and animal welfare groups. In the European Union (EU), public pressure has been a successful instigator to the drafting and continued improvement of comprehensive legislation for animal transport. EU animal transport laws cover aspects such as minimum design standards for livestock vehicles (including ventilation controls), maximum journey lengths before resting intervals, stocking rates, what animals are considered as fit to travel, and general handling and care requirements of animals in transport. These laws are causing debate between northern and southern countries in areas such as maximum journey lengths and vehicle design standards. Some countries such as the UK have also gone to a great effort to adjust national laws in order to incorporate EU transport laws, but countries such as Spain and Italy have not. Typically it is these countries that more often have poor standards of animal welfare, and the welfare of farmed animals has historically been of low priority (Schmidt, 1995). When and how these countries will adopt the comprehensive EU animal transport regulations, continues to be an unanswered and politically sensitive question between EU member states.

INTRODUCTION

In many countries, abattoirs and slaughter industries are becoming centralised into fewer, larger plants. As a consequence, livestock are subjected to travelling greater distances, enduring greater travel times, and exposed to more human handling. This increased stress on livestock, is not only an issue in regard to animal welfare, but it reduces economic value through its effects on meat quality.

The increasing trend of industry centralisation means that the transport distances between farm and abattoir are likely to increase. Also, the trade of live animals is of such a high economic viability, it is unlikely that pressure from animal welfare groups could stop it. However, greater public awareness of animal welfare seems to be increasing in western countries, and as a result there is more pressure on the livestock industry to at least adopt better standards for the farming, handling, transport and slaughter of animals. The transport of livestock in Australia continues to be under increased scrutiny from overseas markets and animal welfare groups.

In the European Union (EU), public pressure has been a successful instigator to the drafting and continued improvement of comprehensive legislation for animal transport. Differences in culture and standard practices in handling farm animals between countries hinder agreements between EU ministers. Ministers who have not had an association with modern livestock practices also do not have the necessary background knowledge to evaluate farming, transport and preslaughter handling, and emotions rather than scientific reality can influence their judgement. When legislation is drafted on animal transport it must be based on reference to biological reality, scientific research and the commercial pressures under which the livestock industry in different countries operates.

This report provides a literature review of research conducted relevant to the aspects in animal transport that contribute to reductions in animal welfare and meat quality. The differences in transport of slaughter stock in certain countries of the EU and Australia, and what influencing factors determine the differences are also discussed. Australian transport conditions have been presented in this report as a comparison to the EU conditions in order to provide a broader approach to the topic. The report is restricted to information regarding commercial transport of slaughter livestock. Information has been compiled not only from scientific reference material, but also from consultations with animal transport operators, abattoirs, European boards of agriculture, animal welfare inspectors and farmer associations in the EU and Australia.

STRESS MEASUREMENTS

When animals are exposed to a novel situation such as transportation, they react by eliciting certain physiological and behavioural functions in order to cope with the situation. These changes can be measured antemortem to indicate how much stress animals are suffering. Stress in the live animal can lead to certain meat quality defects postmortem such as bruising and abnormal meat pH levels. Therefore certain measurements both antemortem and post mortem can indicate preslaughter and transport conditions.

Antemortem

Physiological

When confronted with a potentially stressful situation, Moberg (1985) concludes that an animal has three biological systems available to assist in eliminating or coping with stress (Figure 1). For example an event or stimuli that is perceived by an animal as a threat to its wellbeing such as threat of a predator, encounter with an aggressive peer, or transportation in a vehicle, may stimulate a behavioural response in the animal such as moving away from the threat. If it is unable to do this, the animal may alter its biology by evoking its autonomic and neuroendocrine systems in attempt to cope with the stressor.

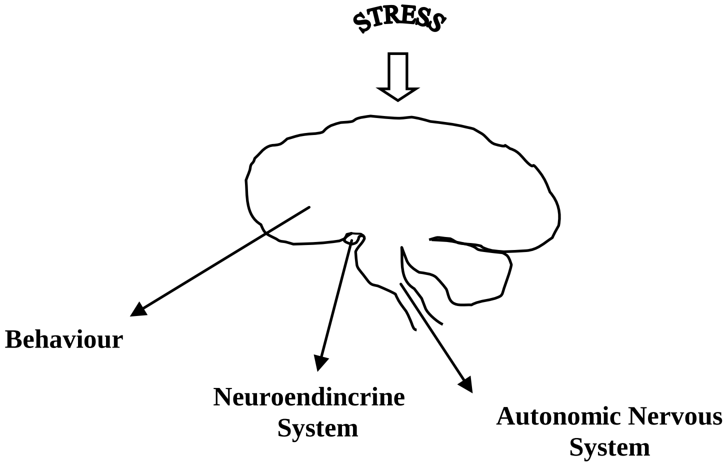


Figure 1. *Types of biological responses available to an animal for coping with stress (modified from Moberg, 1986).*

Various studies cited by Koolhaus and Boohus (1990) have shown that in a species, individuals differ in their coping strategies they use in challenging situations. These coping strategies can be distinguished on the basis of both physiological and behavioural parameters. 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 is therefore indicative of the homeostatic system of the animal failing to cope (Hall and Bradshaw, 1998).

Heart rate is the most common measured sign of autonomic response to stress, and according to much research, a primary neuroendocrine stress indicator is measurement of the secretion of adrenal corticosteroids (Broom and Johnson, 1993; Bradshaw et al.1996a; Baldock and Sibly, 1990; Jacobson and Cook, 1996). However, Moberg (1986) has found in various studies that increases in corticosteroids are not necessarily harmful to an animal. He states that corticol responses to a stimulus only serve as an indicator of significant stress if the adrenal response results in changes in biological function that threaten the animals well being. The change in biological function may or may not alleviate the stressor or ameliorate the effects of the stressor on homeostasis. Regardless of its effectiveness in assisting the animal to cope with the stressor, the change in biological function accounts for the biological cost of the stress, i.e. those resources of the stressed animal that are diverted from pre-stress activities, such as growth, to new biological activities like gluconcogenesis. It is this change in biological function which, when occurring over a prolonged period of time, threatens the animals well being by placing it into a pre-pathological state that may eventually develop into disease.

When an animal perceives a stressful event the brain is triggered and the hypothalamus stimulates the anterior piturity to release ATCH, and this subsequently stimulates glucocorticoid release from the adrenal gland (Sapolsky et al. 1986). These corticoid hormones cause tremendous shifts in carbohydrate metabolism throughout the body and increase circulating energy substrates at the cost of stored energy; they also increase cardiovascular tone, alter cognition, and inhibit growth, immune and inflammatory response and reproduction (Moberg, 1985). Short-term stressors can interfere with biological mechanisms i.e. lowering female reproductive function (Stoebel and Moberg, 1982). For example sorting sheep with dogs three weeks after mating caused early embryonic losses (Doney et al. 1976). The use of electric prods, restraint and other handling stressors can lower immune function in cattle and pigs (Kelly et al. 1981; Mertshing and Kelly, 1983).

Table 1 shows results taken from various research projects on measuring cortisol levels in cattle during different handling procedures indicating base line cortisol levels in different breeds of cattle, and how it changes according to different treatments (Grandin, 1990). Although cortisol levels are highly variable in individual cattle, Grandin (1990) concluded that a mean value of 70ng/mL in beef steers or cows indicates the animals are suffering some sort of stress. Low values (2-5ng/mL) indicate a low stress procedure. Extreme stress was considered to occur when cortisol levels reached 93ng/mL, when cattle were inverted on their back. (Dunn, 1990).

Table 1
Mean cortisol values in cattle during handling procedures (Modified from Grandin, 1990)

Breed/ Sex	*Cortisol level, ng/ml*
	Baseline
Friesian Bulls	2-5
Friesian Cows	2
Angus X Bull calves	3
Angus X Heifer calves	6
	Upright restraint in headgate
Holstein Cows	13
European Mixed sex weaners	24
Brahman X Steers	27
Angus/Hereford X Steers	28
Angus/Brahman X Steers	36
Bos Taurus cattle	45
	Extreme Stress (inverting cattle on back)
European breeds Mixed	93

In sheep, cortisol values during stressful events such as shearing averaged 73ng/ml (Hargreaves and Hutson, 1990), and for isolated sheep and restrained sheep, up to 100ng/ml (Apple et al. 1994). Table 2 outlines different salivary cortisol levels in pigs and sheep recorded by Bradshaw et al. (1996d) under circumstances of rough, smooth, and no transport conditions. This gives an indication of the variance of stress responses between species and individual animals.

Table 2
Concentration of salivary cortisol (nmol/litre) for individual pigs and sheep expressed as an average for each journey type (Bradshaw et al. 1996d)

Animal	*Rough Transport*	*Smooth Transport*	*Control (Baseline levels)*
Pig 1	13.7	9.1	2.1
Pig 2	21.4	8.1	2.4
Pig 3	14.4	9.1	2.0
Pig 4	9.0	7.8	3.4
Sheep 1	15.1	6.2	2.0
Sheep 2	2.3	2.0	1.2
Sheep 3	12.1	3.6	3.4
Sheep 4	15	10.2	1.5

Examples of changes in heart rate levels in beef cattle (Angus-Shorthorn cross) as a result of transport are found in Eldridge et al. (1984a). Heart rates of cattle while travelling were approximately 40% above resting levels in the paddock, but only 15% above those recorded while animals were grazing. Figure 2 shows the heart rate profile of cattle under typical Swedish transport conditions. Heart rates peak at times of loading and unloading, and when other animals were introduced into the truck (Gebresenbet and Eriksson, 1998).

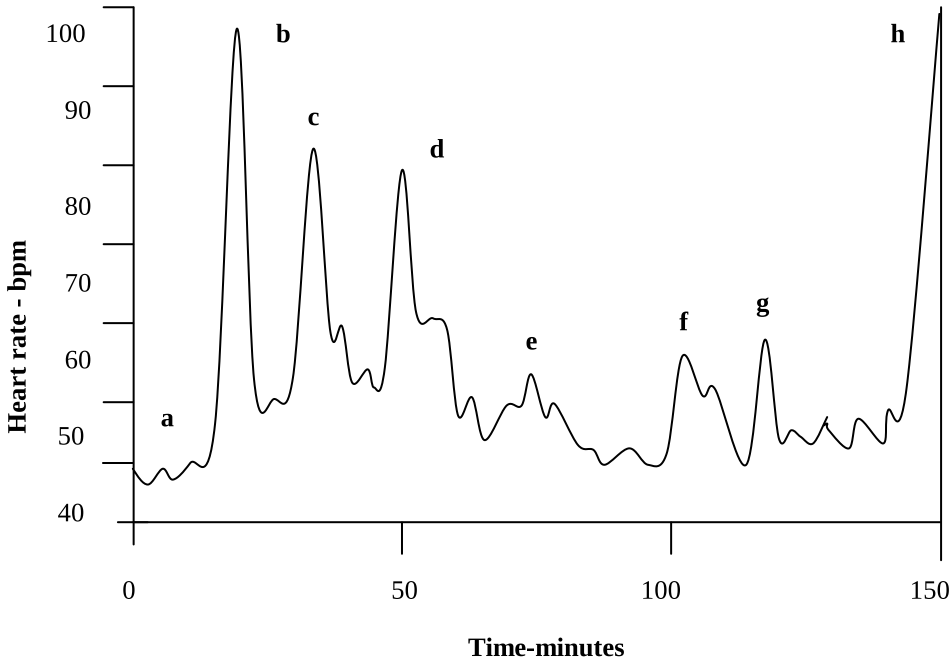


Figure 2. *Typical measured heart rate profile during handling and transport of cattle under Swedish conditions. The measured data positions in the plot indicated by letters include (a) animals at the farm before loading; (b) loading of animals on the truck; (c-g) vehicle starts moving; (d-f) loading and mixing unfamiliar animals on to the truck, d and f denote the second and third farm respectively; (e) transport on rough road; (h) unloading at the abattoir (Modified from Gebresenbet and Eriksson, 1998).*

Warren (1993) found that heart rate in transported horses increased by up to 18 beats per minute compared to horses not transported. Table 3 gives an idea of heart rate and behavioural changes in sheep exposed to various stress stimuli taken in research projects by Baldock and Sibly (1990). They found that while an animal appeared behaviourally undisturbed by a stress stimuli its heart rate could indicate that it was experiencing stress. Also other indicators such as lactate measurements can be extremely variable, and may not necessarily reflect true stress levels in an animal. This demonstrates the importance of measuring and interpreting more than one stress indicator (Broom et al.1996).

Table 3
Heart rate and behavioural response measurements in experiments on the effects of handling and transport on sheep (Baldock and Sibly, 1990)

Conditions	*Experiment duration (min)*	*Heart rate increase (beats/min)*	*Vocalisations (min)*	*% time trotting/ galloping*
Penning	6-13	12	0	0
Spatial isolation	15	0	0	0
Visual isolation	5	28	4.25	5.3
Transportation				
-stationary trailer	20	0	0	0
- moving trailer	20	12	0.25	0
New flock				
- 0-30min	30	49	2.5	4
- 30min-2h	90	22	1.5	0
Driving by sheepdog	12	83	-	42

It has been found that measured stress responses of young calves to transport are much lower than that of older calves (>6months) and adult cattle. Kent and Ewbank (1986) found lower increases in plasma cortisol concentrations (2-3 times greater than baseline levels) as a reaction to transportation in young calves compared to older calves (11 times baseline levels). Knowles et al. (1997) also found that young calves did not show the same marked changes in heat rate, plasma glucose and cortisol levels, as that of older cattle or sheep. Hartmann et al. (1973) as cited in Knowles (1995), found that the reactivity of the adrenals to an ATCH challenge increases with age, and that it is not yet fully developed in one-week old calves. Knowles (1995) agrees with this finding, and concludes that young calves are unable to respond to transport in the same way as older animals due to their undeveloped physiological system. However, this does not mean that the effect of stress such as transport is less severe in very young animals. In fact it is the contrary as Barnes et al. (1975) has shown. Mortality rates were much higher in calves transported at one day old (35%) compared to 4 days old (2%).

Blood enzymes such as creatine phospho kinase (CPK) and lactate dehydrogenase (LDH) can also be measured as an indication of stress in animals (Cockram and Corley, 1991). These enzymes are released into the blood when there is muscle tissue damage or after frightening events, and are generally involved in the body's reaction and adaptation to stress (Grandin, 1980). Deer that were captured and showing frightened behavioural signs, showed large LDH increases (Broom, 1995). Cattle that were transported showed large increases in blood concentration of CPK and lactate compared to non-transported cattle (Scott et al. 1993; Cockram and Corley, 1991). Warriss et al (1998) related stress indices and meat quality, and found that pigs with higher circulating levels of cortisol, lactate and CPK, tended to have meat with higher pH levels. It was also found that pigs with high levels of skin blemish had higher levels of blood cortisol and CPK at slaughter (Table 4). Rougher handling or pigs fighting during transport or lairage probably caused the higher skin blemishes, and these activities also cause increased stress measurements.

Table 4
Indices of stress in pigs whose carcasses showed different degrees of blemish (Modified from Warriss et al.1998)

Stress indicator	***Skin Blemish Score***			
	1 (none)	**2**	**3**	**4(worst)**
N	>930	>1204	>244	>21
Cortisol (ug/100ml)	13.4	11.9	15.1	20.6
CPK (U/L)	682	1211	1554	1801

Studies to determine the amount of stress on farm animals during routine transport often have highly variable results and are difficult to interpret from an animal welfare standpoint. Much of the variability between handling studies is likely to be due to different levels of psychological stress, and there will also be stress responses related to the actual sampling procedure involved and this can influence test results. In general fear responses in a particular situation are difficult to predict because they depend on how the animal perceives the handling or transport experience. The animal's reaction will be governed by a complex interaction of genetic factors and previous experiences.

Behavioural

Behavioural responses as a result of animals being mixed in strange groups have been recorded by Mohan Raj et al. (1991) to include aggressive (butting, pushing) and sexual (teasing and mounting) behaviour. This type of behaviour correlates to increased salivary cortisol levels in pigs (Bradshaw et al. 1996d). Warris et al. (1994) found that the sound level of squealing pigs in an abattoir was highly correlated with CPK measurements. White et al. (1995) also reported that vocalisations in pigs were indicative of stress and correlated with other stress measurements.

Gregory (1998), Warris et al. (1994) and White et al. (1995) give the following description of some general behavioural signs of stress in livestock:

- vigorous tail flicking
- head shaking
- incontinence
- nostril flaring
- spasmodic body shivering
- eye flickering
- head retraction and eye closure.
- vocalisation

Ewbank (1993) suggests that until the environmental stresses are quantified, the biochemical reactions have been recorded, and the damage to animal well being has been identified, changes in behaviour can only suggest stress. Kent and Ewbank (1983) suggest that while behavioural observations can give some indication of the effects of transportation, they have a limited role by themselves as direct, practical evaluators of transport effects.

Liveweight loss

Loss of weight owing to tissue breakdown in fasted animals occurs earlier in monogastric animals than in ruminants, and according to Tarrant (1990) is probably insignificant in cattle during the first 24 hours of fasting. The gut contents can account for 12-25% of an animal's liveweight, and loss of carcass weight during prolonged fasting is due to the dehydration of the carcass tissues and mobilisation of depot fat and muscle glycogen. However the amount of water and amount and quality of feed consumed before fasting influences measures on live-weight loss. Gut fill is larger in animals on high roughage pasture than those fed grain diets, and in hydrated animals (Wythes et al. 1985a). Therefore, it is important to consider feeding patterns before transport when assessing live weight loss as an indication of transport stress.

Liveweight loss in pigs begins almost immediately after feed withdrawal at a rate of between 0.12 and 0.20% per hour (Warriss, 1993; Phillips et al. 1985). A large part of this loss initially is attributable to loss of urine and faeces (Warriss 1987; Cole et al. 1988). In a study by Brown et al. (1999), pigs lost 2.2% of liveweight after 8 hours of transport, but there was no further loss after 16 hours. However after 24 hours transport the liveweight loss increased to 4.5 %, and there was a 2.5% loss in hot carcass weight. Six hours of lairage allowed liveweight to recover to pre transport levels.

Ruminants are generally less susceptible than pigs to exhaustion from lack of nourishment because of their proportionally larger guts, and the fact that the rumen acts as a store of nutrients and water. Cattle loose weight most rapidly during the first 12 hours that they are without feed and water, and the rate of loss slows progressively (Cole et al. 1988; Wythes et al. 1984). Liveweight losses tend to be greater when both feed and water are unavailable under conditions of high ambient temperatures (Wythes et al. 1985a). Unfed steers lost 4.7% of their pre transport liveweight after 3 days fasting and transport, and 9.1% after 5 days, while steers that were fed hay in lairage, lost 3.8% and 6.7% respectively (Wythes et al. 1989). However, Shorthose and Wythes (1988) found by averaging data collected from 26 publications (Figure 3), liveweight losses in fasted cattle were about 7% after 12 hours, 9% after 24 hours, 10% after 48 hours, and 11% after 72 hours. Rates of loss appear to be up to three times higher in cases of water deprivation over long transport duration (Warriss, 1993). Some research has shown that providing electrolytes as a pre mix drench or in drinking water to cattle before transport reduces liveweight loss, DFD incidence (Schaefer et al. 1995) and carcass weight loss (Jacobsen et al. 1993; Scott et al. 1993).

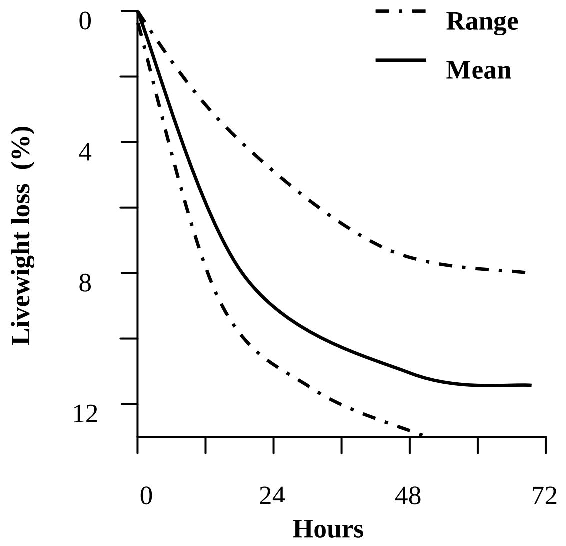


Figure 3. *Typical liveweight loss, as a percentage of initial liveweight, in cattle deprived of feed and water (with or without transportation) (Shorthose and Wythes, 1988).*

Thompson et al. (1987) reported a greater rate of liveweight loss in lambs transported for 7 hours compared to those simply fasted with access to water for a similar period of time (0.2% versus 0.1% initial liveweight/hour respectively). Once given access to water the transported lambs regained weight before slaughter, and carcass characteristics were similar to those non-transported lambs. Rate of liveweight loss between 0 and 72 hours was reported at 0.14% per hour, and a carcass loss of 0.85% per hour (Table 5) (Warriss, 1993). Liveweight losses in goat kids have been reported at 7, 10, and 12% after 1,2, and 3 days fasting respectively (Greenwood et al. 1992).

Table 5
Influence of fasting on weights (kg) of body components in sheep (Warriss, 1993)

	Fast (Hours)			
	0	**24**	**48**	**72**
Livewt at slaughter	32.3	30.6	29.8	29.2
Hot carcass wt	16.4	16.0	15.7	15.4
% Loss in chilling	4.7	4.7	4.5	4.2
Liver weight	0.63	0.52	0.48	0.45
Gut contents	4.6	3.6	3.7	3.3

Even if feed and water are offered to animals during and after transport, some animals show reluctance to drink due to stress, and /or unfamiliarity with the feed/drink system. Friend et al. (1998) found that less tame horses were more reluctant to drink during transit than tame horses. More research is needed in the area of feeding and watering behaviour of livestock under transport and lairage conditions.

Mortality

Of all farm species, pigs generally present the greatest risk of sudden death as a consequence of transport stress (Lambooij, 1988). Lister (1988) reported that 70-80% of pre-slaughter pig deaths occurred during transport. According to many researches (Guárdia et al.1996; Warriss, 1998) the main causes of preslaughter mortality include environmental factors (handling and weather) and the genotype. The influence of genotype complicates the interpretation of the influence of other factors. Therefore variation in mortality rates seen for example in the EU (ranging from <0.1%->1.0%) (Warriss, (1998), can be partly attributed to differences in the inherent stress-susceptibility of the pig populations of that country. Pigs that are homozygous for the recessive gene known as the halothane gene have an abnormality in their muscle metabolism making the pig highly sensitive to stressful situations such as transport. Pigs with this gene are also more sensitive to halothane, and observing pig behaviour when drugged with halothane, is one way in which to detect stress sensitive pigs. Stress sensitive breeds such as the Pietrain and Belgian Landrace, or genotypes containing genes from these breeds are much more likely to die in transit (Geers et al. 1994). Grandin (1980) reported that stress susceptible pigs have up to 10 times the death rate when handled than normal pigs. During long periods of transport in tropical climatic conditions McPhee et al (1994) reported that mortality is different between three genotypes (Hal^-Hal^-1.4%, Hal^-Hal^+2.6% and Hal^+Hal^+13.7%). The use of homozygous (Hal^+Hal^+) or the heterozygous (Hal^+Hal^-) genotypes in sire populations, has been justified by the greater muscle development and lower fat and bone proportions than in lines free of the Hal^+ gene (Oliver et al. 1995). Therefore pigs that are stress sensitive have generally evolved as a result of producers over-selecting for leaner pork. Reactions these pigs might display prior to death include unusually high body temperatures, extreme excitability, trembling, panting, and skin covered in red patches. These pigs are likely to suffer heat stroke, shock, and circulatory collapse even when transported short distances (Lambooij and van Putten, 1993). In countries with a higher proportion of stress susceptible genotypes, mortality is generally higher (Warris and Brown, 1994). Mortality rates of up to 1% have been reported in countries where stress sensitive breeds are common such as Germany and Belgium (Gregory, 1998), and in countries with low stress sensitive breeds, mortality is around 0.03% (Barton Gade, 1994). Table 6 indicates pig mortality rates quoted in various European research studies.

Table 6
Pig transport mortality rates indicated in some European countries (Warriss, 1998; Barton Gade et al. 1994; Swedish Meat Research and Development Corporation, 1999; Guárdia et al. 1996)

Country	*Mortality (%)*
Denmark	0.03-0.09
Sweden	0.05-0.07
UK	0.06-0.07
Spain	0.07-0.55
Italy	0.16
Belgium	0.3-1
Germany	0.5-1

Pigs are sensitive to high ambient temperatures because they cannot eliminate heat through their skin as they do not have functioning sweat glands (Guárdia et al. 1996). Therefore hot weather generally increases pig mortality rates (Warriss and Brown, 1994; Lambooij and van Putten, 1993; Abott et al. 1995). The effect of humidity is unclear, however surveys conducted in England (Figure 4) on cause of death of pigs in transport, showed that the highest pig mortality occurred when conditions were hot and wet (Abott et al. 1995).

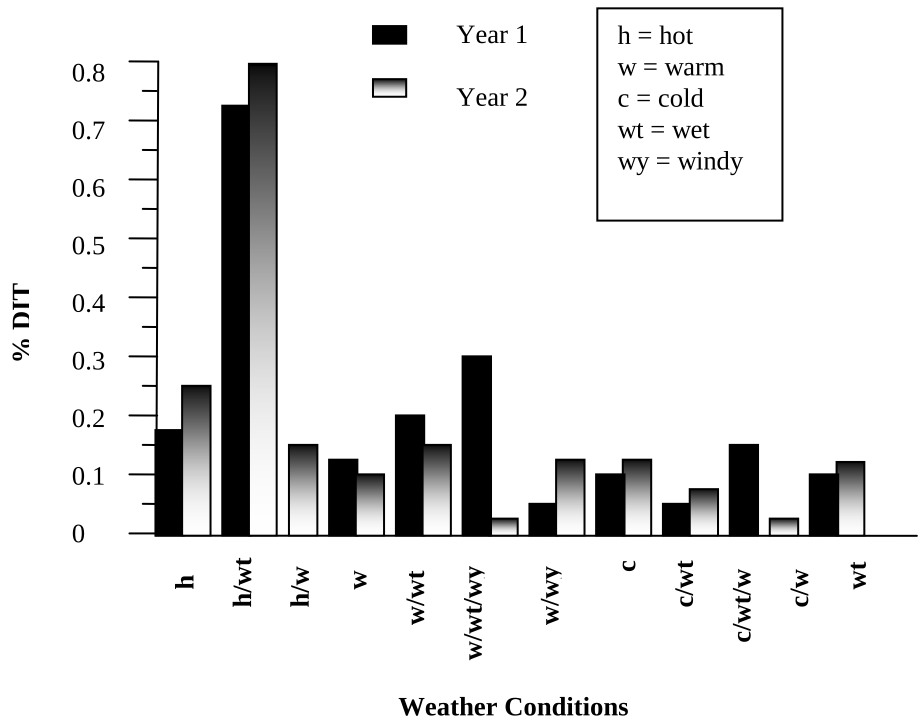


Figure 4. *Percentages of deaths in transit (DIT) relative to weather condition (Abbott et al. 1995).*

Warris and Brown (1994) reported a curvilinear relationship between pig mortality in transport and temperature. Above about 15 to 17°C the detrimental effects of high temperatures become far more serious (Warriss and Brown, 1994). The detrimental effects of warm weather conditions can be controlled if appropriate management is taken such installing thermo regulation in trucks, or transporting stock in the cooler parts of the day or at night, or showering pigs in transport or lairage (Guárdia et al. 1996).

Feeding pigs on the day of transport increases the risk of pig deaths (Warriss and Brown 1994; Guárdia et al. 1996; Möller, 1999). In Spain, it was shown that more pigs died if fasted for more than 18 hours before transport (1.95%), compared to below 18 hours (Guárdia et al. 1996). The results of this study, and from studies by Guise (1990), indicate that farm feed withdrawal for pigs prior to transport is best between 12 -18 hours.

Abott et al. (1995) reported that a higher percentage of deaths in transport occurred when pigs were classed as dirty (covered in excreta) at loading (Table 7). Poor management such as a sudden change in feed and extra feed the night before transport were stipulated reasons for dirty pigs. Dirty pigs also indicate lower hygiene practices from the producer, which can predispose pigs to disease. Abbott suggested that short-term stress does not have as great an effect on deaths in transit as long term stress such as hygiene and weather conditions.

Table 7
Number of pigs considered 'clean' or 'dirty' at loading and the levels of DIT observed (Abbott et al. 1995)

Year	*Clean pigs* No. carried	*Clean pigs* % DIT	*Dirty pigs* No. Carried	*Dirty pigs* % DIT	*Significance (two sample t test)*
1	79, 569	0.08	50, 181	0.13	$P<0.05$
2	72, 962	0.08	58, 182	0.15	$P<0.05$

Warriss (1998) cited information from a various reports that indicated that more pigs die on bottom decks of vehicles than on top or mid decks, as well as pigs situated behind the cab, possibly because of poorer ventilation on these parts of the vehicle. Warriss and Brown (1994), reported 0.061% of pigs died in transit, and 0.011% died during lairage in the UK per year (i.e. approximately 10, 500 pigs per annum). The proportion of deaths during lairage ranged from 0.04 to 0.21% with an average of 0.15%. According to Warriss and Brown (1994) there is no evidence that mortality rates among transported pigs in the UK have increased over the last 20 years. Barton Gade (1994) reported that removing stress susceptible pigs from breeding programs, and general improvements in the standard of transport conditions for pigs in Denmark, resulted in significant decreases in mortality rates of transported slaughter pigs. Annual statistics for transport and lairage mortality in pigs in one abattoir in Denmark were measured at 0.03% in transport and 0.014% in lairage (Barton Gade et al. 1992). In a later report mortality in transported slaughter pigs was reported at 0.09% in Denmark, and in Portugal 0.16% (Barton Gade, et al. 1994). Figure 5 shows mortality rates in transported sucker pigs in Sweden from 1995 to 1998, and figure 6 shows general pig mortality rates in transported pigs from 1985-1998.

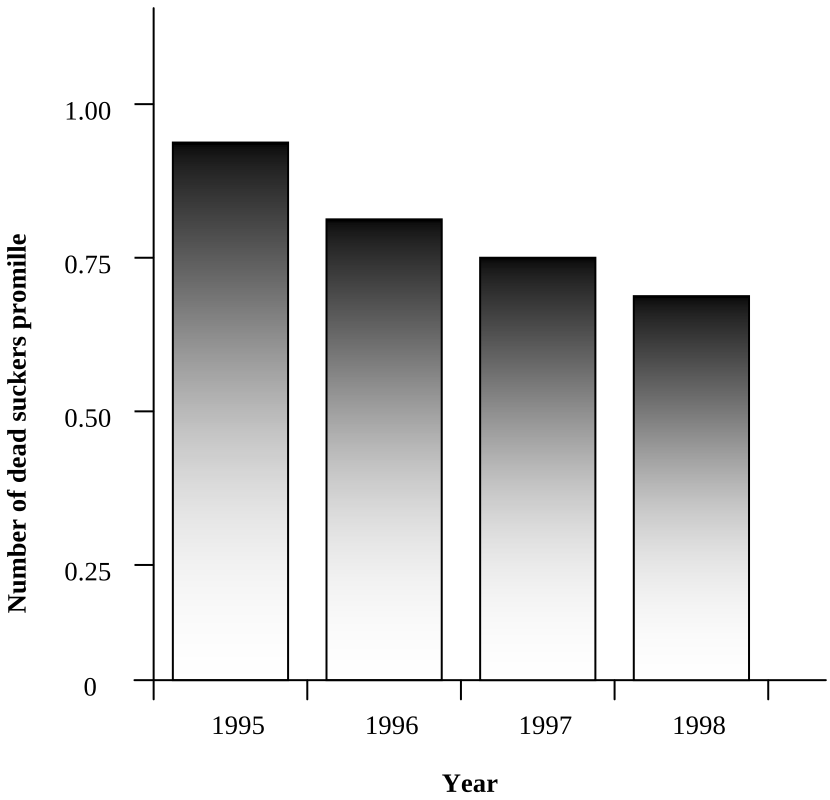


Figure 5. *Mortality rate of suckers during transport and lairage in Sweden (Swedish Meat Research and Development Corporation, 1999).*

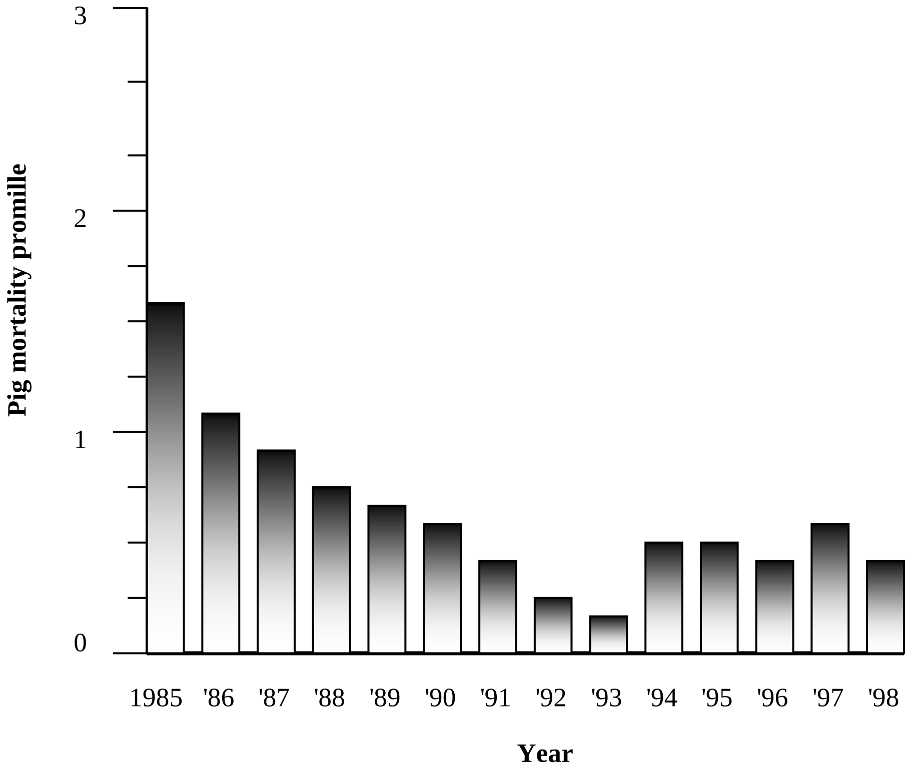


Figure 6. *Pig mortality rates in transport and lairage in Swedish abattoirs 1985-1998 (Swedish Meat Research and Development Corporation, 1999).*

In 1985 the mortality rate of transported slaughter pigs in Sweden was 0.16%, and in 1998 it was 0.05%. The mortality has reduced due to selection against stress susceptible pigs, and also from general improvements in the design of transport and slaughter facilities (Swedish Meat Research and Development, 1999). Fabiansson et al. (1979) estimated the financial losses to Sweden from pig mortality during transport and lairage at three million Swedish crowns per year.

In Spain, a survey of 5 abattoirs reported mortality rates in pigs during transport and lairage ranging from 0.07% to 0.55%. The lower mortality rate in one abattoir was contributed to it being the least noisy of the abattoirs surveyed, and the easiest to drive pigs to stunning point (Gispert et al. in press). In a survey of 16 Spanish abattoirs on pig mortality rates in transport, Guárdia, et al (1996) reported an average mortality over a 3-year period of 0.22%. Hot weather and poor design of lairage and abattoir facilities were indicated as very important factors in influencing these mortality rates. The estimated cost of pig mortality to the Spanish meat industry is approximately 8 million ECU, with mortality rates ranging from 0.03-0.59%. The size of the variation indicates that financial losses of an abattoir slaughtering half a million pigs per year could vary from 17,000 to 335,000 ECU (Guárdia, et al 1996).

Mortality rates in transported broiler chickens in Sweden has been recorded at 0.1% (Swedish Meat Research and Development Corporation, 1999) and in the UK it was estimated by Warris et al. (1992) at 0.19%. This study also found that in a survey of 1113 journeys involving 3.2 million broilers, that the longer the journey time the higher mortality rate. When journeys lasted less than 4 hours the incidence of dead on arrival (DOA) birds at the processing plant was 0.16%, and for longer journeys the incidence was 0.29%. In another survey conducted by Gregory and Austin (1992), the rate of birds DOA was 0.19%. It was found that 47% of the birds had died of congestive heart failure, and 35% died of trauma injuries. There have been reports of 50% mortality in end of lay hens being transported from Spain to the Netherlands, and hot environmental temperatures and poor ventilation in the trucks were thought to be the main predisposing factors (Gregory, 1992).

Research by Knolwes et al. (1995) has shown that sheep are generally better able to cope with long distance transport by road than other livestock. This is reflected by the generally low transport moralities for sheep recorded within Europe (Knowles et al. 1994c). In the UK mortality rates of sheep in transit recorded at one abattoir was about 0.01%, and in lambs 0.018% (Knolwes et al. 1994a). Within the UK, Knowles et al. (1994b) found that mortality rates were higher among lambs which had been through auction markets (0.031%) compared to those sent direct to slaughter from producers (0.07%). However, the situation is graver in the live sheep export trade from Australia to the Middle East. The death rate on voyage is sometimes as high as 6%, and 8% for goats, with average mortality rates of 2% (Higgs et al. 1999). The highest mortality for a single voyage officially recorded was 16% (Higgs, 1991). Gregory (1992) reported that most research on sheep mortality during sea travel identified journey duration as the major effect on mortality rates. When oil prices are high the ship sets a low speed to conserve fuel and thus the journey lasts longer and the mortality is higher. Mortality is also higher when unloading at Middle Eastern ports due to the little natural ventilation on the stationary ships which can hold up to 60,000 animals. Unloading rates depend on whether the sheep are off-loaded on to trucks (at a rate of 800 sheep per hour) or into quayside feedlots (3000 sheep per hour) (Higgs,1991). Mortality during shipment over long distances has been contributed to three main causes i.e. exhaustion from lack of nourishment (inanition) (47%), *Salmonella* (27%), and trauma and stress (12%) (Higgs et al. 1991). Salmonellosis is thought to be secondary to inanition (Richards et al. 1986). Seasonal variation also influences mortality rate in transported sheep (Higgs et al. 1991). Sheep that come off dry summer pasture are attuned to fat mobilisation and these sheep are better able to cope with a feed change and harder conditions. This persists during the journey and mortality is about 0.8%. Sheep off lush spring pastures however, have entered a phase of liveweight gain; there is a transient period of lipolysis at the beginning of the trip, and even though these sheep have ample fat reserves, mortality is higher (3.3%)(Richards et al. 1991). A mortality rate of 45.5% (RSPCA- Australia, 1999) was reported for a sea shipment of live cattle from Australia to Asia. This was due to the sudden change in diet from lush winter pastures to pellet feed.

It is suggested that in northern Australia, 0.1 to 0.2% of cattle die in road transit (Wythes, 1994). Death rates have been reported at 1.4 to 2.8% for the Northern Territory and Kimberly area of western Australia, while in southern states, mortality rates in transport are thought to be lower (Wythes, 1994). This is because in northern Australia, cattle are often transported longer distances, in hotter weather, and in poorer condition. Cattle in well-fed and healthy condition are better able to cope with long distance transport than cattle in poor condition. Shorthose and Wythes (1988) indicated that cattle deaths in transit in northern Australia were 0.44% when the annual rainfall was normal and 0.54% when the rainfall was 30% below average, contributing to lower feed availability and thus cattle in poorer condition.

Knowles (1995) reported that young calves i.e. under one month of age, are not well adapted to cope with transport and marketing, often suffering relatively high rates of morbidity and mortality, both during, and in the few weeks following transport. Barnes et al. (1975) showed this in a report where calves were trucked at 1,2,3 or 4 days of age and which were not slaughtered but grown on (Figure 7). The younger the calves were when trucked the higher the subsequent mortality until 4 days of age. In the UK, a survey of calves exported from England to Italy found mortality rates in young calves of 1% (Smith, 1985). Nix (1994) indicated that veal processors in the UK expected about 5% mortality loss in calves, and that primary losses occurred in the first 3 weeks of the calves' arrival at slaughter plants.

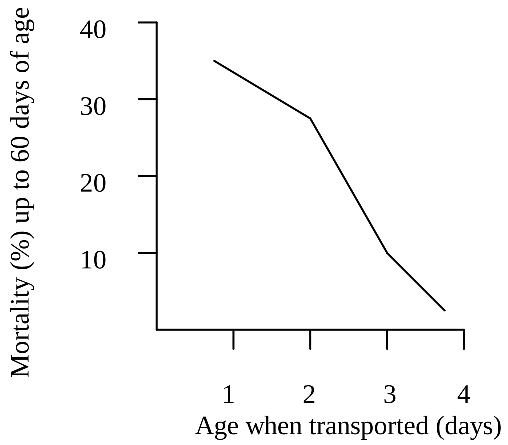


Figure 7. *Effect of age at transport on subsequent mortality in calves (Barnes et al. 1975).*

Regardless of the standard of transport and management of slaughter animals, different breeds and individuals within the breeds will display different reactions to stress. In consequence, given the same transport stress, some animals will die whilst others will survive with out obvious detriment. Any mortality during transport or in lairage however, indicates compromised animal welfare and the death involves total economic loss of the value of the carcass. Careful management of transported animals, selection for breeding stress resistant animals, improving the design of animal handling and transport systems, especially for adequate ventilation, and ensuring animals are fit for transport in the first place, are human controlled factors that can reduce mortality rates in transported livestock.

<u>Postmortem</u>

<u>pH, DFD, PSE</u>

It is beyond the scope of this report to review meat science literature in detail, and comment will be restricted to how events in pre-slaughter handling and transport of livestock can effect meat quality.

Pre slaughter handling and transport stress of slaughter stock can cause the following meat quality defects:

- dark cutting beef (DCB)
- dark, firm dry (DFD)
- pale, soft exudative (PSE)
- Bruising
- Skin damage (pigs)

The first two meat quality defects (DCB and DFD) are actually the same phenomenon, except they are occurring in different animal species. Some authors use DFD to explain the meat quality defect in pork, lamb and beef meat, while other authors prefer to use DCB for beef only, and DFD for lamb and pork only. In some of the research cited in this report, the dark meat condition was referred to in the original literature as DCB, but for the purposes of this report it will be referred to as DFD.

Transport stress causes an animal to have a surge in energy demand required to help the animal adjust to the change in environmental conditions and keep balance on the journey. Stress stimulates the release of adrenaline and this will trigger glycogen breakdown in the muscles. After death, when the catabolism is anaerobic, glycogen in the muscles is converted to lactic acid. Where there is depleted glycogen levels in the live animal from stress, the muscles at slaughter will have insufficient glycolytic substrates to allow the muscle to acidify properly. This leads to high pH values 24 hours after slaughter (ultimate pH) and the meat subsequently becomes DFD meat (Gregory, 1998).

DFD meat has a very high water-binding capacity therefore a dry or sticky texture. It is aesthetically unacceptable to consumers, favours bacterial growth, has low palatability and one of the most economic defects is that it has a short shelf life, making it unsuitable for vacuum packaging (Eldridge, 1988b; Gregory, 1998). Meat pH is a useful but general guide for measuring meat quality. Meat at pH levels exceeding 5.8 becomes darker in colour as the pH rises (Figure 8). Normal pH levels drop from pH 6.8 to 5.6 within 24 hours. Exposing animals to long-term stress conditions, i.e. extreme environmental temperatures, being mixed with unfamiliar cohorts, long transport and lairage times, and prolonged rough handling, can contribute to causing DFD in slaughter animals (Tarrant, 1988; Eldridge, 1988b).

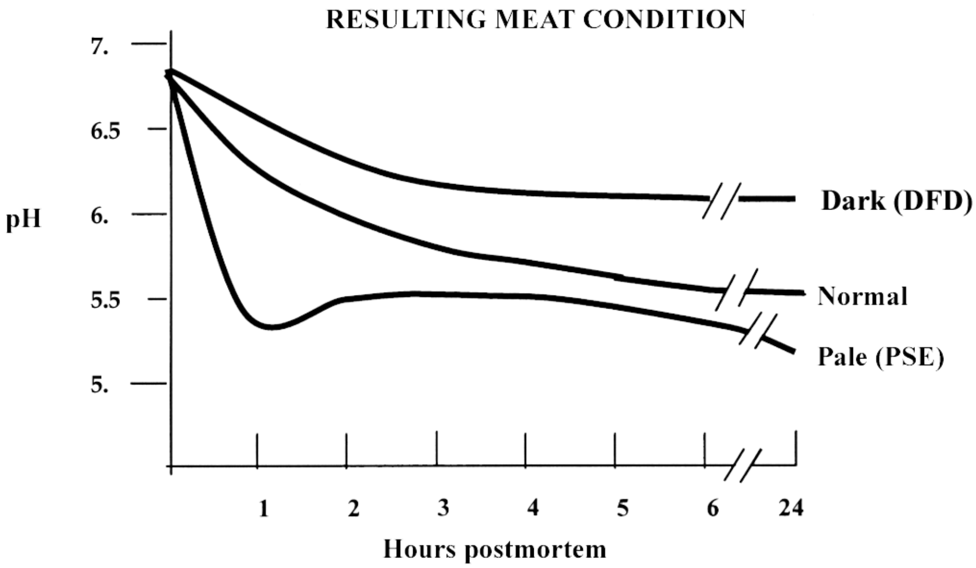


Figure 8. *pH decline in relation to hours after slaughter and meat condition (modified from Gregory, 1998).*

When animals are mixed in unfamiliar groups in a confined space, there is inevitably some type of aggressive behaviour to determine the social hierarchy. This takes the form of butting, pushing, mounting and chin resting. This behaviour causes the animal to use lots of energy and the consequences on meat quality include DFD. In bulls it took three to seven days for muscle glycogen concentrations to replete and produce low ultimate pH levels after they were mixed for as short as 5 to 12 hours (Warriss 1984). DFD tends to be more common in entire (non-castrated) animals, especially young bulls, and seems to be less frequent in female and castrated animals (Table 8) (Brown et al. 1990; Kenny and Tarrant, 1988; Purchas and Aungsupakorn, 1993; Ramsgaard Jensen, 1996).

Table 8
The effect of animal category on incidence of DFD (Brown et al. 1990)

Animal	*Total Number*	*Number DFD*	*%*
Bull	649	52	8.0
Cow	252	15	6.0
Steer	2929	11	0.38
Calf	270	10	3.7
Heifer	716	10	1.4

There is limited research available on the differences in meat quality in pigs of different sexes. However, entire male pigs are considered leaner, faster growing and more efficient than castrates, and this explains the low level of castration now practised in the UK (Wood, 1993). Results collected by Barton Gade (1993a) showed that DFD frequency increased by 2% when pigs were not fed and held in lairage over night compared to pigs slaughtered on arrival. The reasons for higher DFD rates were attributed to pigs fighting. Research indicates a lairage of 3 hours will generally optimise meat quality in pigs if they are kept in small groups and not mixed prior to slaughter (Warris et al. 1992).

In Australia and New Zealand, one of the main causes for DFD in lamb is through excessive exercise. Mustering sheep and transporting them long distances can almost completely deplete muscle glycogen levels, and recovery can take up to 17 hours (Devine and Chrystall, 1988).

PSE meat occurs in pigs and turkeys (Gregory, 1998). In PSE meat formation, there is no shortage of glycogen. Instead the animal is physiologically stressed by the pre-slaughter handling process, and this causes the muscles to acidify at a rapid rate while the carcass is still hot. The combination of low post mortem muscle pH (Under pH5.6) and high muscle temperature is the critical situation which leads to PSE formation. PSE meat has a pale grey colour, low palatability, shrinks more during cooking, is difficult to cure correctly and has a very low water holding capacity causing cut surfaces to appear wet (Barton Gade et al. 1996; Wood, 1993).

The relationship between genetic susceptibility to stress and meat quality has been demonstrated to be the main cause of PSE meat in pork (Lambooij and van Putten, 1993). Grandin (1994) believes that genetics is probably the single most important factor contributing to the prevalence of

PSE pork in the USA. This factor limits the possibilities of improving quality via handling (Barton Gade et al. 1996). Table 9 shows stress level sensitivities in different breeds of commercial pigs. The Pietrain breed for example, has the advantage of high lean meat content and thick muscle, but the disadvantage of PSE and other manifestations of the porcine stress syndrome (Wood, 1993).

Table 9
Stress sensitivity in different pig breeds (Gregory, 1998)

Stress resistant	***Mildly stress sensitive***	***Stress sensitive***
Irish Large White	Dutch Landrace	Piétrain
Australian Large White	French Landrace	Belgian Landrace
French Large White	Swedish Landrace	Poland China
American Yorkshire	Swiss Landrace	German Landrace
British Large White	British Landrace	
Duroc	Danish Landrace	
	Norwegian Landrace	
	Australian Landrace	
	Irish Landrace	
	American Hampshire	
	Dutch Yorkshire	

DNA testing for the halothane gene allows breeding companies to eliminate the gene from their pig stocks altogether, or to concentrate it into only one of the parent lines. Heterozygotes are then expected to be intermediate between the parent lines for leanness and conformation, but to have a close to zero incidence of PSE. However, some research suggests that even in \`halothane-free´ lines, muscle quality is still negatively correlated with lean content, albeit at a lower level (Wood, 1993). The reduction of PSE incidence in Denmark over 7 years resulting from test and cull programs for stress susceptibility is shown in Table 10.

Table 10
PSE % in different breeds of pigs in Denmark (Barton Gade, 1992)

Breed	*1983/84*	*1984/85*	*1985/86*	*1986/87*	*1987/88*	*1988/89*	*1989/90*
Landrace	16.8	12.8	12.1	9.5	10.4	6.6	6.4
Large white	6.8	3.4	7.0	2.7	1.4	2.3	0.9
Duroc	3.5	0.8	0.0	0.6	0.0	1.5	0.0

In Spain, a research project on halothane gene frequency and PSE frequency in 5 large abattoirs, showed that the abattoir with the highest frequency of the n gene had 12.7% PSE carcasses, while the abattoir with the lowest n gene frequency had 1.5% PSE carcasses. It was also shown that the leanest carcasses also had the greatest frequency of the n allele (Figure 9) (Gispert et al. in press).

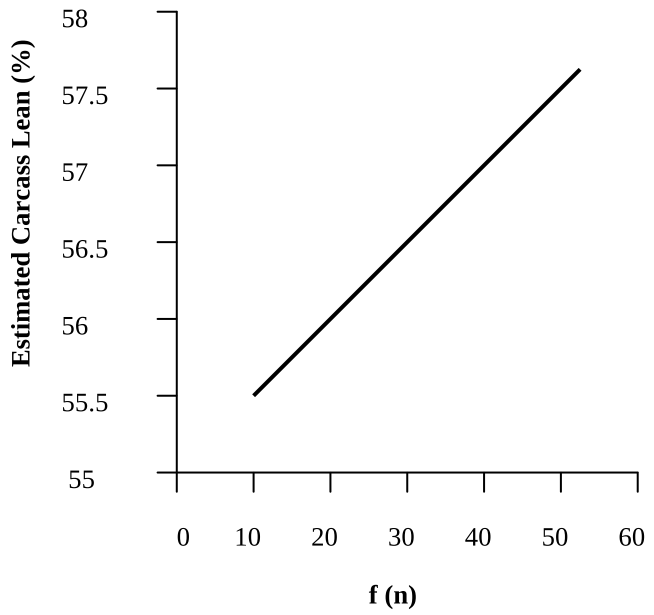


Figure 9. *The relationship between n gene frequency and estimated lean meat (Gispert et al. in press).*

According to Brownlie (1988), visual assessment of meat is not a consistent method for determining DFD or PSE. A more consistent method is by way of a pH meter. The pH limit for normal, DFD and PSE meat varies from country to country, animal species, and further from different meat processing companies. It also varies depending on how it has been determined e.g. by a microbiologist, by a meat inspector in an abattoir, or by a trade organisation, and also from what muscles the pH levels are measured. These variations can sometimes lead to misinterpretation of DFD or PSE incidence. In beef and lamb meat in Australia, USA and New Zealand, the following researches considered optimum ultimate meat pH levels to occur at pH 5.5, and high pH values are considered at pH 6 or above (Gregory, 1998; Eldridge, 1988b; Wythes, 1994; MLA, 1999; Tarrant, 1988; Grandin, 1990). However in Sweden, Möller et al. (1994) and Gebresenbet and Eriksson (1998) considered beef DFD to occur over pH 5.8. Danish researchers defined optimum pH levels for beef meat to be between 5.4- 5.9 (Hald and Ramsgaard Jensen, 1992). Homer and Mathews (1998) from the Meat and Livestock Commission UK, considered pH values greater than 6.5 in pigs to be indicative of DFD, also in agreement with Australia (Trout 1992), while Warriss (1993) considered pH 5.8 and above to be DFD. Danish and Spanish researches defined DFD in pork as occurring at ultimate pH above 6 (Barton Gade, 1993a; Gispert. et al. in press). Wythes (1994) suggests that the dark cutting appearance in beef occurs at different pH levels according to the age of the animal. For example, consumers who had the opportunity to purchase meat from older, heavier animals considered beef with a pH of above 5.9 to be dark. When consumers were buying meat from lighter, younger animals, a pH of above 5.7 was considered dark (Shorthose, 1980). Finnish microbiologists stated that in any meat with pH levels over 5.8, the free glucose content is practically zero, and this results in bacteria utilising amino acids instead of glucose as a source of energy, which leads to the rapid formation of off flavour (Puolanne, 1988).

Studies by Möller et al. (1994) indicated 10-25% of beef meat in Sweden, especially that of young bulls and calves, developed DFD. Malmfors and Brendov (1988) reported 15% of calves slaughtered in Sweden had DFD meat. In the UK, levels of 4.1% DFD in beef has been reported (Browne and Whan 1990). Shorthose (1988) estimated that 8% of carcasses (excluding bulls) had high pH values at a Queensland abattoir in Australia. In the USA, DFD in the beef industry causes greater losses than bruising, and is said to cost the industry U$5.00 for each animal slaughtered (Grandin, 1993c).

Morris (1994) estimated the prevalence of DFD in sheep meat in Australia, to be around 15% for lambs and Warner et al. (1990) estimated 14% of mutton could be classified as DFD when defined as pH of 6 or over. In New Zealand, DFD is said to occur in 8% of lamb, and 12% of mutton (Graafhuis and Devine, 1994). Lamb meat tends to be less prone to the effects of metabolic exhaustion than pork or beef (Gregory, 1992), and meat buyers and consumers seem to be less sensitive to meat quality issues in lamb than for other meats (Gregory, 1998).

In America, after transport mortality, PSE meat causes the largest financial losses to the pork industry (Grandin, 1993). The incidence of PSE in the pig industries of Scandinavia was reported at 2% in Sweden, and 3% in Denmark (Barton Gade, 1993b). A British study showed that at the retail level each PSE carcass causes an additional £1.13 loss (Smith and Lesser, 1982). Warriss et al. (1998) reported in a survey of pig meat quality measurements from abattoirs of 5 different countries (UK, Netherlands, Denmark, Italy and Portugal), a very low DFD incidence (less than 1%). In Australia, Warner and Eldridge (1988) reported overall incidences of PSE and DFD of 10% and 15% respectively in pigs killed in Victorian abattoirs. Trout (1992) recorded average incidences of 32% for PSE and 15% DFD in five large Australian pork processing plants, with considerable individual variation (5-65% and 0-45% respectively). In surveys in America Cassens et al. (1992) reported 16% of hams to be PSE and 10% DFD. In the U.S. the National Pork Producers Association (1994) reported that the U.S. pork industry loses U$0.34 per pig due to PSE. Data presented for Canadian pigs by Fortin (1989) imply very high incidences of PSE meat, with averages ranging from 20 - 90% for batches of commercial pigs subjected to various pre-slaughter handling procedures.

Table 11 demonstrates survey results from different researchers that indicate the significant variations in the percentage of DFD and PSE incidence occurring in different countries. It must be kept in mind that it is very difficult to assess the extent of DFD and PSE problems because of the lack of single definitive characteristics which are universally agreed upon on to define DFD and PSE. What is considered as DFD in one country, may not be so considered in another. Therefore when comparing figures on PSE and DFD incidence, it is important to know at what pH level was set to define DFD and PSE. However, it seems universally accepted that DFD and PSE meat quality defects constitute problems of immense economic proportions to the meat industries world-wide (Barton Gade, 1994; Cassens et al. 1992; Grandin, 1999a; Gregory, 1998; Warris et al. 1990b).

Table 11
Reported DFD and PSE incidence in different countries

Country	*Reference*	*Meat Defect*	*Species*	*Incidence*
Sweden	Möller et al. 1994	DFD	Bull beef	10-25%
	Möller 1999	PSE	Pork	2%
Denmark	Barton Gade 1994	PSE	Pork	<3%
	Barton Gade 1994	DFD	Pork	1%
UK	Browne & Whan 1990	DFD	Beef	4.1%
	Homer and Mathews 1998	DFD	Pork	0 %
Spain	Gispert et al. in press	DFD	Pork	12.5%
	Gispert et al in press	PSE	Pork	6.5%
Australia	Shorthose 1988	DFD	Beef (not bulls)	8%
	Warner et al. 1990	DFD	Lamb	15%
	Warner& Eldridge 1988	DFD	Pork	15%
		PSE	Pork	10%
New Zealand	Graafhuis & Devine 1994	DFD	Lamb	8-12%
USA	Cassens et al 1992	PSE	Pork	16%
	Cassens et al 1992	DFD	Pork	10%
Canada	Fortin 1989	PSE	Pork	20%

Bruising

When an animal is bruised, blood vessels are ruptured and blood infiltrates the surrounding tissues (Gracey and Collins, 1992). If handling and transport constructions are poorly designed, animals can strike against fences, gates, and sharp corners, often bumping the hindquarters against obstacles. This situation is made worse if stock handlers force the animals too quickly, causing them to bash into each other, and possibly fall especially if the ground surface is covered with wet slippery manure. Grandin (1995) reported that cattle, which were handled roughly during weighing and loading at a feedlot, had almost double the bruising rate over their bodies, compared to cattle that had been walked quietly on to the scales and trucks. The highest percentage of bruising was located in the most valuable part of the carcass - the loin area. Due to rough transport and handling conditions, cows rested after transport periods of 9, 15 and 20 hours had more bruising than those transported non stop for 36 hours and rested for the same period in lairage (Wythes, et al. 1988a).

It is suggested that the age of a bruise can roughly be estimated from its appearance post-mortem with a bright red bruise likely to be recent, up to 10 hours old, and a dark red bruise approximately 24 hours old (Gracey and Collins, 1992). McCausland and Miller (1982) developed histological techniques to differentiate bruising occurring immediately before or after stunning, as well as 8, 24 and 48 hours before slaughter. They found that at least 43% of all bruises were incurred after the cattle arrived at the abattoir, most of them just before stunning. Ten percent happened before or during transport, and the remaining 47% could not be attributed to a specific time. However, according to Warriss (1990) there is no reliable technique yet developed to determine exactly when and how animals have been bruised.

There is some research to suggest that there are no differences in bruise scores between animals transported direct from farm to slaughter compared to those that have been through the auction system (Hourder et al. 1982; Jarvis, et al. 1996a). However, most research has found otherwise, and generally longer marketing times are associated with greater bruising. For example McNally (1995) reported from two surveys consisting of a total of 16,000 cattle carcasses, that bruising occurred in 7.8% of cattle bought from live auction centres, compared to 4.8% bruising in cattle bought direct from farms. Also a greater weight of tissue was rejected for bruising from market cattle (401 g) than those direct from farms (98 g). Stick-marking, a bruise formed as a result of the animal being struck by a stick like object, was also greater in market cattle (2.5%) than in those which were farm supplied (0.9%). Figure 10 shows that bruises (other than stick marks) were higher in stick-marked animals (35%) compared to the total slaughter population (6.5%). Similar results were found in a study by Jarvis et al. (1995) and also in studies by Eldridge et al. (1984b) and McNally and Warriss (1997) where market cattle had significantly more evidence of animals been hit with sticks, and increased bruising correlated with increased stick marking. Similar observations were made in marketed sheep (Cockram and Lee, 1991; Jarvis and Cockram, 1994; Jarvis et al. 1996b; Knowles et al. 1994a). The use of sticks probably increases bruising rates because it increases the risk of the animals bumping into objects. Geverink et al. (1996) found that the use of sticks to move pigs contributed considerably to skin damage.

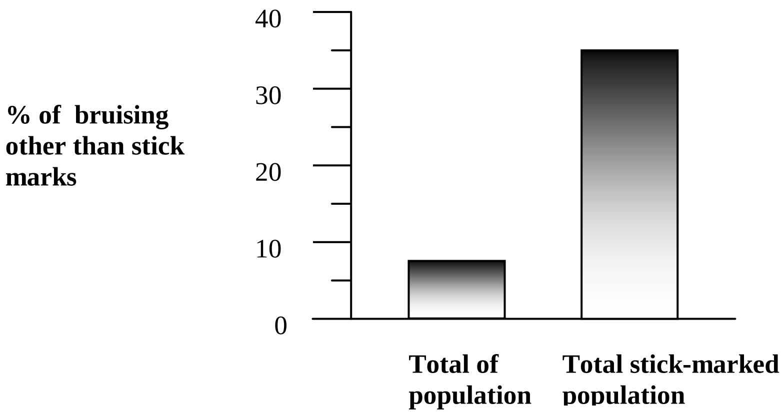


Figure 10. *Percentage of bruising in the total slaughter population and stick-marked population (NcNally, 1995)*.

Work conducted by Tarrant et al. (1992a) and later by McNally and Warriss (1997) showed transport distance had no effect on bruising rates on cattle. Danish researchers found that significantly more bruises were observed when cattle were tied up during transportation than when they were transported loose, and the difference was most pronounced for cows where 63% arrived tied up. Fourteen percent of tied cows had deep bruises compared to 9 % of those arriving loose on the truck (Hald and Ramsgaard-Jensen, 1992). Standard practice is to transport cattle tied if they are kept in a tethered system.

Wythes, (1979) showed that horned cattle transported to slaughter had significantly higher bruising than polled cattle. The average bruise trim was 1.5kg per carcass in the horned group, and 0.9kg in the polled group. Shaw et al. (1976) also found similar results, and in his study the percentage of carcasses and weight of bruise trim was twice as much in horned cattle than polled cattle transported to slaughter. In a study on preslaughter conditions in Danish cattle, Ramsgaard Jenson (1996) found that horned animals also had higher pH levels. Eight percent of horned young bulls had pH above 6.2 whereas only 3% of dehorned young bulls developed pH above 6.2. Tipping of horns in Australia is an established practice in slaughter cattle production. It has been shown however, that this practice is ineffective in reducing bruising rate (Wythes, 1979). Cattle with un-tipped and tipped horns had had significantly more ($P<0.05$) bruising than polled cattle. Despite this information, it has been estimated that in Australia approximately 36% of cattle are horned (Wythes, 1979). De-horning of young animals or better still, the breeding of polled animals is recommended to reduce potential bruising rates.

Cockram and Lee (1991) found a 66% increase in bruising from lambs sold through auctions, and Knowles et al (1994a) found a 27% increase, compared to lambs sent direct to slaughter. The additional handling and transport involved in selling livestock through the market system prior to slaughter increases injury risk due to greater stick use on animals, making them more likely to bump into objects (McNally, 1995; Jarvis et al. 1996a). An extensive survey in Western Australia indicated that approximately 2% of lamb carcasses, and 10-20% of sheep carcasses, were sufficiently bruised to cause down-grading (McDonald et al. 1981). Studies in the UK have quoted 1.25% of downgraded lamb carcasses due to bruising (Knowles et al. 1994a). Cockram and Lee (1991) found visible bruising in 71% of lambs and 49% of ewes, in a total of 2010 animals, most of it on the side and neck. The most likely causes of the bruising were contributed to mounting behaviour of other sheep and wool pulling by the stock handlers.

Bruising rates in horses were surveyed at 2 different abattoirs in USA and were found to be as high as 25% (Grandin et al. 1999). Most of this bruising was attributed to fighting. Horses are not usually bred specifically for meat production, and are invariably sold to slaughter due to illnesses or injury, or because they are no longer required for use in equestrian sports. Little attention to date has been given to the welfare of slaughter horses, as most horsemeat is processed into manufactured meat, and horse carcass meat quality is not such an economic concern as it is in other meat producing animals.

Severe bruising in stock is obviously a sign of compromised animal welfare. Bruising also causes economic loss to the beef, lamb, pork and poultry industries as severe bruises have to be trimmed off, and sometimes the entire carcass condemned (Browne, 1992; McNally and Warriss, 1996). Production lines can be congested while bruised tissue is removed adding to labour costs and reducing overall efficiency of slaughter plants. It is difficult to find accurate figures on economic losses from bruising. Estimates for bruising in Australia for the meat industry have been quoted at A$42 million per year (Eldridge and Winfield, 1988), and for the cattle industry A$36 million annually (Blackshaw et al. 1987). In America, Grandin (1995) estimated bruising losses in cattle cost US$22 million annually. Figures collected from Colorado State University in 1992 and 1995 (sited by Grandin, 1999b) equated bruising losses of US$1.00 per animal from feedlots and $3.91 per head of range raised beef. Browne (1992) reported 11% of grass-fed and 1% of grain-fed (feedlot) cattle in Australia were rejected as unsuitable for export to Asian markets due to bruising. In England, bruising losses and carcass down grading has been equated at £4.5 million in the cattle industry (McNally and Warriss, 1996). In pigs, PSE and DFD cause greater economic losses than bruising (Grandin, 1993c).

<u>Carcass weight loss</u>

The carcass is that part of the body remaining after bleeding, removal of the head, feet, and hide, evisceration and other normal carcass dressing procedures (Wythes, 1994). However, dressing procedures are not the same world wide, so precise comparisons of results for carcass weight from different experiments are not possible. However, research results do give an indication of carcass weight losses that can occur through animals being fasted and transported.

For unfed cattle given access to water in lairage, average daily losses in carcass weight are estimated at 1.3% (range 0.8-2.3%), 2-11 days from truck loading to slaughter (Wythes, et al.1988a,b). Once cattle were offered water in lairage, transportation per se did not appear to reduce carcass weight in cattle transported under 24 hours (Wythes, et al. 1981). However, carcass weight loss in calves have been reported at about 5% after 24 hours of fasting and transport (Gregory, 1998). Carcass weight loss in sheep was reported to occur at 3-4% and 6-7% for 1 and 2 day fasting respectively (Morriss, 1994). Warriss et al. (1987) reported carcass weight loss in lambs to vary from 0.08% to 0.14% per hour over 72 hours fasting.

It is estimated that carcass weight loss in pigs begins between 9 and 18 hours after the last meal (Warriss, 1993) and that rates over fasting periods of 48 hours or more, varied between 0.06 and 0.14% per hour. Where pigs have not been given access to water during the whole period of fasting, the rate of loss tends to be higher. Overall, an average working figure of 0.1% per hour would appear reasonable (Warris, 1990).

FACTORS IN FARM ANIMAL TRANSPORT THAT EFFECT ANIMAL WELFARE AND MEAT QUALITY

Animal behaviour

Different livestock species, genetic variations within species and life experiences combine to influence how an animal behaves while in the transport and preslaughter process. Although farm livestock have been domesticated over time, they still remain a prey species. The instinct to avoid being attacked by predators is inherent and therefore most farm animals are sensitive to novelty. An important objective in handling animals is to minimise their level of fear, because at high fear levels, animals behave in a self-protective way by fleeing or fighting (Hemsworth, 1993). Therefore to improve ease of movement and minimise injury to stock, it is important that stock persons have a good understanding of animal behaviour principles.

Livestock have a wide, monocular field of vision (Warriss, 1990). Pick et al. (1994) suggests that there may be an extensive blind area at the ground level, and moving livestock may not be able to use motion parallax or retinal disparity cues, which allow for depth perception. To see depth on the ground, the animal would have to stop and lower its head. This may explain why livestock often lower their heads and stop to look at strange things on the ground. They have a blind spot directly behind and poor vision at ground level when walking with their heads up. Consequently they are prone to confuse floor irregularities and shadows as actual physical barriers (Grandin, 1999c).

Recent research on colour vision in farm animals (Pick et al. 1994) shows that they are dichromats with cones (colour sensitive retina cells) most sensitive to yellowish green and blue purple light. Dichromatic vision may make the animal more sensitive to seeing sudden movement. The brains fear centre (amygdala) is also activated when the animal sees sudden movement (Grandin, 1999c). This is why people working with livestock should use slow deliberate movements (Grandin,1989a).

Part of the difficulty of moving animals into new surroundings is their fear of unfamiliar conditions (Grandin, 1989a). A new type of flooring material, a change in lighting or penning walls, or even a simple object such as a bucket lying in a lane-way, can cause livestock to balk and stop moving along. This is made worse if the livestock are being driven along aggressively with out being given time to investigate the new area. Good even lighting will help facilitate stock along races, and shadows and bright spots should be minimised (Grandin, 1999c).

Unexpected or loud noises can also be highly stressful to stock (Grandin, 1989a; Talling et al. 1996). Sheep exposed to loud noises in a slaughter plant had elevated cortisol levels (Pearson et al, 1977). Thus, design of transport and handling facilities should avoid causes of loud noises, for example installing rubber stops on gates and squeeze chutes will help reduce noise levels (Grandin, 1989a). Researchers in Canada found that sound from people such as yelling or whistling had a greater effect on heart rate of cattle than equipment sounds such as banging gates (Waynert et al. 1999). Handlers can keep animals calmer if they avoid sudden intermittent noises and use low pitched sounds instead (Grandin, 1999c).

Cattle and sheep move well in single file races, as they move along in pasture in single file, and are motivated to maintain visual contact with each other (Grandin, 1994). If animals bunch up, handlers should concentrate on moving the leaders instead of pushing animals from the rear. Pigs move better in groups where visual and physical contact can be kept (Hemsworth, 1993). Loading ramps for pigs can be designed to utilise this social behaviour (Figure 11). The outer walls are solid to eliminate visual distractions, while the inner partition allows for visual contact (Grandin, 1983).

Figure 11*:* *A loading ramp designed to promote the following behaviour of pigs (Grandin, 1999a).*

Pigs will move along races better if a solid background such as a board is used behind them to prevent them turning back. Domestic animals are instinctively social creatures that prefer to remain in flocks or herds. The flocking instinct differs among species, being very strong in sheep and less so in cattle and pigs. For this reason it is difficult to separate one sheep from the flock, but less difficult to separate a cow or a pig (Gonyou, 1993). Sudden isolation can be highly stressful to livestock (Rushen, 1986), and in the event of separation from the herd they can become highly agitated and injure themselves and their handlers. Penning either next to or with other animals will calm them (Grandin, 1989a). However, care must be taken when mixing unfamiliar groups of animals. For example, pigs grouped with unfamiliar pigs causes aggression amongst one another (McGlone, 1985) and the same occurs for bulls (Price and Tennesson, 1981). Social regrouping animals in these cases in transportation is detrimental to their welfare and should be avoided.

The animals flight zone (Figure 12) is important to consider when handling livestock. Livestock will move away when the flight zone is penetrated and stop when the handler retreats. Livestock can be moved most efficiently if the handler works on the edge of the flight zone.

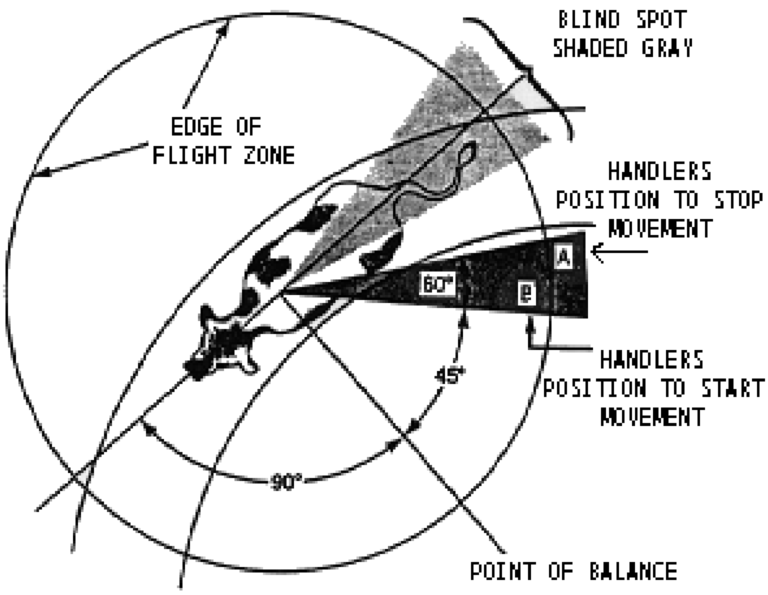


Figure 12. *Diagram of the general flight zone of an animal (Grandin, 1999a).*

A good livestock handler exploits the flight behaviour of animals, and will work from a position of 45° to 60° behind the animal's shoulder on the edge of the flight zone (Grandin, 1993b). The flight distance will depend on the animals previous handling experiences, and as the flight distance decreases the animals are more tractable (Grandin, 1980; 1993a). Deep penetration of the flight zones should be avoided, as it may cause the animal to turn back on the handler, or attempt escape over the sides of the race. The aim of figure 13 is to demonstrate that if a handler moves inside the flight zone of livestock in the opposite direction of desired movement, it helps to move stock forward in a loading race (Grandin, 1993c).

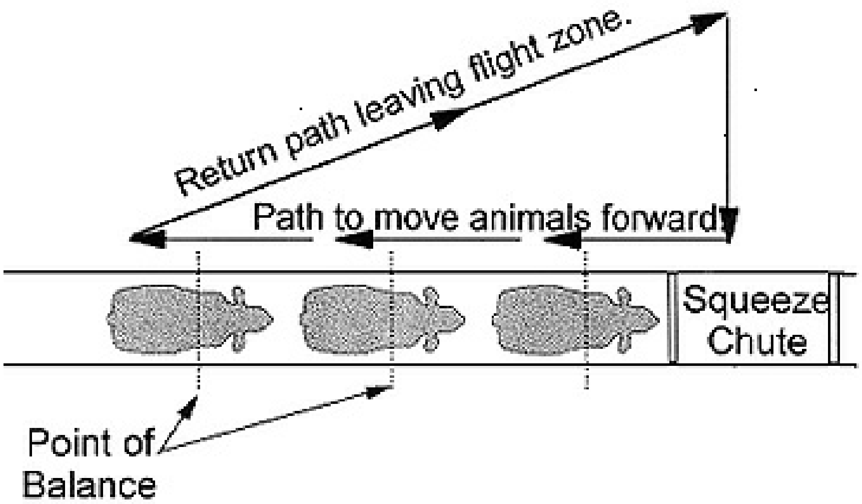


Figure 13. *Handler movement pattern to keep livestock moving in a loading race (Grandin, 1993c).*

Curved races can be effective in promoting the movement of cattle and sheep (Lapworth, 1990). This is because it provides for the animals desire to maintain visual contact with other animals and prevents the lead animal from seeing what it is at the other end of the race, until it is almost there. As a leading animal moves around the curve, the following animals must also move to maintain visual contact. In a straight race, the following animal can maintain visual contact even if a large gap exists between it and the lead animal (Gonyou, 1993).

Animals can have stronger or weaker reactions to human handling influenced by their breed type. For example the Piétrain breed of pig is more difficult to handle than the Duroc (Gregory, 1998). Breed differences in 'temperament', or the reaction of cattle being held in a squeeze chute are noticeable and the trait has been shown to be moderately heritable (Heisler, 1979). Fear of the human in sows is also heritable (Hemsworth et al. 1990). Individuals within breeds will also differ genetically due to the heritable nature of this trait, and this explains some of the differences reported in handling responses for pigs (Lawrence et al. 1991). However, husbandry systems under which animals have been reared is probably more significant than the effects of genetic differences between breeds or types themselves (Kabuga and Appiah, 1992).

Cattle which have had frequent, gentle and early contact with humans are usually tamer and easier to handle than unhandled cattle (Ewbank, 1993). According to Sato et al. (1984) handling restricted to the first month of a calf's life, had little influence on its subsequent behaviour, but regular handling of heifers up to 9 months was shown to permanently reduce their fear of man (Bouissou and Boissy, 1988). Hemsworth et al. (1989) however, found that handling pigs up to 8 weeks of age made the pigs less fearful of humans later in life than pigs that were not handled. Although this suggests that exposure to humans improves the response of animals to handling, none confirm that the periods of treatment were more sensitive than any other period in the animal's life. For example, Boivin et al. (1992) handled cattle at two sensitive periods, after birth and after weaning, and compared stress responses to cattle handled six weeks later. There was evidence to show that repeated exposure to humans reduced the stress responses the animals had when handled later in life, but the period of life during which the initial exposure to handling occurred, did not affect the results.

The way in which livestock are managed from birth can have significant effect on their behaviour towards transportation. Trunkfield and Broom (1990) found that calves reared in crates were more stressed by transportation than calves that were group reared. Being forced into new groups seemed to be the most disturbing factor for the crate reared calves. They were also much weaker due to lack of exercise and less able to cope physically to transport than group reared calves. Research has shown that intensively reared dairy cattle had much lower stress responses to being handled and restrained than cattle raised in an extensive environment (Laye et al. 1992). Fordyce et al. (1988) found cattle of the same genotype, but scored as having poor temperament due to being infrequently handled, had heavier bruise scores than cattle with quieter temperaments. In a study conducted by Jacobson and Cook (1996), bulls that were familiarised with loading on to a transport vehicle, and fed hay in the vehicle, had lower heart rates during and after transport, than those transported for the first time (Figure 14). Research by Bradshaw et al. (1996d) indicates that pigs find loading and transport stressful (cortisol levels increase from baseline levels), but they habituate to repeated transportation. Friend et al. (1998) found that transport trained horses had no obvious increased cortisol concentrations when transported, compared to penned and rested horses. Slaughter pigs are frequently kept in restricted environments generally with low levels of stimulation. As a result they may have little capacity to adapt to novel stimuli or new environments such as transportation (Broom and

Johnson, 1993). Grandin, (1989b) found that indoor pigs reared in a barren environment with low stimulation, were more aggressive, excitable and harder to move in a single file chute, than pigs reared in an outdoor environment. Gregory (1998) also mentions that out door reared pigs are calmer to handle in a novel environment, showing less exploratory behaviour than intensively reared pigs. Training livestock to better prepare them for coping with transport could actually reduce the losses in meat quality (Grandin, 1989b; Gregory, 1998).

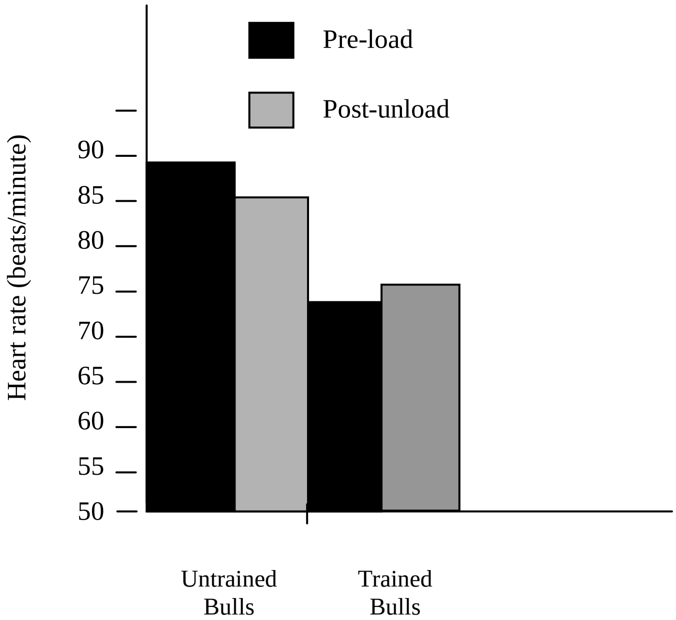


Figure 14. *Mean heart rate levels of two groups of bulls, one familiar with transport, loading and unloading (trained), and the other not (untrained); before and after two hours transportation to an abattoir (Jacobson and Cook, 1996).*

van Putten and Elshof (1978) conducted a research project where pigs were exposed to a circuit of varying transport obstacles including different degrees of loading ramp steepness, narrow and wide races, different pen sizes, etc. The stress levels were assessed at each obstacle by way of observed behaviour and measured heart rate levels. They found that out of all the obstacles in the circuit, steep loading ramps at an angle of 30^o caused the greatest amount of stress to the pigs. They also discovered that if they stressed the pigs by trying to aggressively force them to move, once the heart rate exceeded 220-240 beats per minute, the pigs would lie down and not move. The use of the electric prod was found to have little advantage in the movement of the pigs, and the more often it was used the greater the stress response. There is also a suggestion that electric prodders cause pectoral haemorrhages (Lambooij and van Putten, 1993). Electric prodders should have rounded points, and electrical pulses should not exceed one second between pulses.

Different species and different ages of livestock have different behavioural responses to transport. Bradshaw et al. (1996b) found that pigs are more prone to travel sickness and may require space and a substrate in order to lie down, while sheep spend most of their time standing and also walk and socially interact while on a journey. In a study by Brown et al. (1999) pigs lay down during most of a 24 hour journey, and appeared to be asleep, with few changes in position. Compared with other species cattle prefer to stand during transport, but they do lie down at the latter end of a long journey after about 16 hours (Tarrant et al. 1992a; Knolwes, 1999). Young calves however, lie down much more than adult cattle during transport as calves spend significantly more time resting and sleeping than adult cattle (Kilgour and Dalton, 1983). However Kent and Ewbank (1986) reported that calves in transport spent much less time lying (10%) than calves in a normal environment (65%). Calves also reduced rumination and increased urination and defecation. These results are similar to the report by Atkinson (1992) where 7 to 15 day old calves were found to spend less time resting and sleeping when transported than non-transported calves. Calves also often react very little to external stimuli, and can be difficult to load and unload from a vehicle (Grandin, 1999c). Flat loading ramps reduce these problems and the use of plastic streamers or a rattle such as a tin full of nails, make better alternatives to electric prodders. These differences indicate that greater emphasis should be placed on developing animal welfare and handling guidelines that are species specific (Bradshaw, et al. 1996c).

Social regrouping

Stable social hierarchies develop in animals reared together in groups. These hierarchies become disrupted when unfamiliar animals are mixed together for transport to slaughter. The fighting to establish the new level of hierarchy can lead to animal welfare and meat quality problems. As mentioned earlier, consequences of regrouping animals include skin lacerations, bruising, and DFD. Warriss (1994) found that regrouped pigs showed elevated cortisol and CPK levels, and evidence of muscle glycogen depletion, indicating that fighting is a stressful experience.

In Europe where many animals are reared in individual stalls, in order to meet an abattoir contract only a few animals may be drafted out, and it is inevitable they will be exposed to regrouping either on the truck or in lairage. This can have severe effects on subsequent meat quality. For example bulls that were individually reared, transported in separate pens on a truck, and then exposed to regrouping in lairage, had 80% dark cutting meat, compared to 0% in loose housed bulls slaughtered immediately on arrival at the abbattoir (Browne and Whan 1990). Price and Tennessen (1981) found a tendency towards more DFD carcasses when small groups of 7 bulls were mixed compared with larger groups of 21 bulls. In one abattoir the prevalence of DFD fell from 47% to 8% when the lairage system was changed from group penning to individual penning (Gregory, 1998).

According to Geverink et al. (1996) it is still common practice to mix pigs from different rearing groups of a producer during transport and lairage. Bradshaw et al. (1996a) showed that unfamiliar pigs fought during even short journeys and had higher levels of salivary cortisol compared with unmixed pigs. Several other studies have shown that mixing pigs increased the frequency of skin blemish values (Geverink et al. 1998; Guise and Penny, 1989; Karlsson and Lundström, 1992) and reduced their resting behaviour (Barton Gade et al. 1992). Geverink et al. (1996) showed that skin damage increases in proportion to the time pigs spend in lairage. Rundgren (1988) found transporting unfamiliar pigs together increased weight losses. It has been indicated that mixing 200 pigs from various farms resulted in less fighting than mixing 6-40 pigs. The advantage of the larger group being that an attacked pig has an opportunity to escape (Grandin, 1990). However, Barton Gade (1992) suggests that pigs are especially excited when in large groups. In Sweden, as standard practice, pigs are penned, transported and moved in groups of 20 and in Denmark groups of 15. Research by Barton Gade, (1992) has shown that transporting and lairaging pigs in small groups (<20) reduces aggressive behaviour between pigs, and is therefore beneficial to their welfare and meat quality. Warris (1984) found that boars were between 1.3 and 2.5 times as likely to produce carcasses that were downgraded because of serious damage than non-boars. Although the mixing of unacquainted cattle and pigs is known to cause increased stress and reduced meat quality (Grandin, 1999b; Bradshaw et al. 1996a), this is often not the case when mixing unacquainted sheep (Hall and Bradshaw, 1998).

In the transport of slaughter horses regrouping is a particular welfare concern. Grandin, et al. (1999) found that the main cause of severe injuries in slaughter horses was fighting. In fact 51% of carcass bruising in horses slaughtered at 2 abattoirs was attributed to fighting. It is recommended that horses are observed carefully, and aggressive horses are separated. It is better if horses in lairage are not confined in small pens where a subordinate horse cannot escape an attacker.

Stockmanship

An important factor that influences the ease or otherwise of handling animals, is the extent and severity of previous handling experiences (Ewbank, 1993; Hemsworth et al. 1993). Work conducted in Australia has shown that high levels of fear of humans by pigs as a consequence of aggressive handling can reduce growth and reproductive pig performance (Hemsworth et al. 1997). This exemplifies the effect adverse human handling could have on the later performance of livestock in situations such as transportation.

When loading animals, stockmen may try to speed the movement of animals though the stock are going in the right direction, and in doing so cause the animals to misplace their feet, slip and injure and bruise themselves.

In situations where it is necessary to use goads of any type especially electric prodders, they should be used as little as possible as they contribute to animal stress (Grandin, 1993b). They should never be applied to sensitive parts of the animal such as the eyes, ears, nose or anus. When an animal refuses to move and goes down in a loading race, it is often pointless to use a goad repetitively on the animal. It is better to back off for a minute and let the animal calm down and allow it to decide that it wants to get up (Gregory, 1998). Teaching handlers the basic principles of handling can also greatly reduce the use of electric goads in slaughter plants. In America, after employers were instructed in the use of behavioural principles for moving cattle in the yards, crowding pens and race, it was possible to move 90-95% of the cattle through the entire system without the use of electric goads. The handlers were able to keep up with the slaughter line while using the electric prodder much less (Grandin, 1997b). Geverink et al. (1996) found that the speed of driving pigs up to slaughter was no different when done quietly with no use of the electric prodder, compared to those driven along with an electric goad.

Cockram and Lee (1991) reported that lambs in wool were more frequently bruised (1.28%), than those not in wool (0.93%), and this difference was attributed to the pulling of wool during handling. In countries where dogs are used to facilitate the movement of sheep such as in the UK and Australia, it is recommended that the dogs be muzzled. McDonald et al. (1981) reported a doubling of the number of bruises in the hind leg area of sheep sold through the sale yard system where dogs were used to move stock, compared to sheep that were sold direct to abattoirs.

Livestock that become recumbent during transport are a major welfare concern and can be exposed to great suffering if not treated humanely and efficiently. Cattle that are down and unable to get up, are sometimes dragged from trucks by drivers who are impatient (Grandin, 1994). These animals are also exposed to trampling from other stock. American research has shown that 33% of veal calves arrived at auction too young to walk. As a consequence, calves were thrown and dragged from transport vehicles (Grandin, 1994).

Common handling problems that occur when moving pigs include the following:

- Pigs often respond to forced or hurried movement by fighting against it instead of moving with it.
- In unfamiliar situations they are inclined to return to where they came from, and are prepared to fight to get back to the familiar site.
- Due to the short- range vision of pigs, they often gradually explore new situations. This makes them slow to move, and handlers often do not have enough patience for this.
- Pigs do not necessarily respond to pressure from other pigs pushing from behind. Moving pigs in small groups allows the handler to encourage forward movement from the leader pig.
- Frightened pigs tend to pack together making handling difficult. When pigs are difficult to move, a solid board used to push quietly behind them helps in most cases (Grandin, 1999b; Gregory, 1998).

Obviously road conditions effect how animals travel. Stock on short trips but submitted to transport over rough roads and through cities where a lot of stop starting is required, will be more stressed than those travelling long distances (over 8 hours) on smooth roads. Table 12 indicates the relationship of loss of balance and driving events during 1-hour journeys with Friesian steers.

Table 12
The relationship between loss of balance on a moving vehicle and driving events during road transport of Friesian steers (Kenny and Tarrant, 1987)

Driver events (in order of frequency of occurrence)	*% of cases of loss of balance*
Travelling Smoothly	5
Cornering	16
Two events coinciding	35
Braking	26
Acceleration and gear change	4
Swaying of truck from side to side	5
Starting the truck	0.5

Most loss of balance occurred during braking, cornering, and braking when on rough surfaces. Bradshaw et al. (1996d) found in a study on the transport of pigs and sheep on rough and smooth journeys, that cortisol levels were highest on the rough journey for both species, and pigs were travel sick on the rougher journeys. Eldridge (1988c) found that during the road transport of beef heifers, the average heart rate was lower when the vehicle was travelling smoothly on highways compared to rougher country roads or in suburban areas with many intersections.

Stock handlers working in the transport or abattoir industry deal with large numbers of livestock every day. It is inevitable that they have a different outlook towards the animals they are handling to that of the farmer or owner of the stock, whose main concern would be to sell a healthy animal. The main concerns for the stock handler are more likely in terms of the efficiency of the flow of livestock, and handling ease. The repetitiveness of handling large numbers of stock, and being under pressure to move these animals to keep up with contracts and abattoir slaughter lines, can have the effect of desensitising animal handlers to the welfare needs of the animals they are handling. Regular education of stock handlers in the area of animal behaviour and the consequence of poor handling could help prevent this situation occurring.

Temperature regulation

Improperly ventilated trucks can result in extreme discomfort for animals in warm humid weather. Hot weather can lead to increased PSE frequency in pigs (Barton Gade, 1993b), and DFD meat in all livestock (Grandin, 1994). In Spain, a survey of DFD and PSE occurrence in 5 large pig abattoirs, showed a higher PSE incidence in summer and higher DFD carcasses in winter (Gispert et al. in press). Homer and Mathews (1998) reported similar results. Optimal environmental conditions for livestock are 15 - 20°C at 50-80% relative humidity (Grandin, 1997b, Lambooij and Engel, 1991). Augustini and Fischer (1982) found that pigs travelled most comfortably at 19°C at 60% humidity. Figure 4 (page 10) demonstrates the relationship between pig mortality and hot humid weather in Europe. The importance of effective ventilation in trucks was demonstrated in Denmark, when statistics showed that pig mortality was halved over one year as a result of mechanical ventilation being installed in the abattoirs transport vehicles (Barton Gade et al. 1996).

Ventilation rate during transport should be adopted to the inside temperature of the truck compartment, which will reflect the combined influence of heat flowing to and from the outside to the inside and the heat produced by the animals (Lambooij, 1982). The inside temperature of the truck can quickly escalate in very hot conditions in a stationary truck. Even in a well-ventilated pig transport truck, temperature can vary by up to 5°C in different compartments (Barton Gade et al. 1996). If the truck has no means for continuing ventilation while stationary, livestock should not be transported during the hottest part of the day. Showering of cattle and pigs before and during transport can reduce heat stress in very hot conditions (Lambooij and van Putten, 1993). In warmer conditions at above 24°C with high humidity, space allowances for pigs should be increased by at least 10% of normal rates (Lambooij and van Putten 1993; Australian Bureau of Animal Welfare, 1998). Danish results have clearly shown that good ventilation is essential to reduce transport mortality (Barton Gade, 1993a). For example mechanical ventilation using double-sided walls, halved transport mortality in a single deck vehicle over a year at one abattoir (Table 13) (Nielsen, 1981, as cited in Barton Gade, 1993a).

Table 13
Mortality rates in pigs transported and lairaged with and without ventilation (Nielsen, 1981)

Mechanical Ventilation	*Number of Pigs*	*Transport (% Loss)*	*Lairage (% Loss)*	*Total (% Loss)*
With	119,373	0.24	0.68	0.92
Without	218,416	0.46	1.06	1.52

Barton Gade (1993a) reported that drilling holes 20 cm from floor level along the sides of a truck body halved transport mortality during a summer period compared to an identical vehicle without holes. A low tier height (900mm) in combination with low ventilation gaps (150mm) gave a 50% increase in heart rate compared to larger ventilation openings and/or higher tier heights. Thus adequate ventilation is essential in trucks using low (less than 900mm) tier heights (Christensen and Barton Gade, 1995).

Calves are unable to closely regulate their body temperature and like pigs, in colder conditions below 15 degrees, they should be bedded with straw or dry wood shavings (Knowles, 1995). In extreme cold (-12°C and below), air vents should be closed to prevent rain or sleet blowing in. Wind chill can quickly kill stock on the back of a trailer if they are exposed. Cattle exposed to cold conditions and fasted prior to slaughter had more DFD carcasses (12.5%) than cattle fasted and kept dry in a shed (0%) (Warner et al. 1990). Eldridge and Winfield (1988) reported when steers were transported to slaughter in open air trucks, along the same roads and to the same abattoir, bruising was greater in steers when transported in wet weather than in other weather conditions. According to Lambooij and van Putten (1993) pigs will freeze to death or become frost bitten by temperatures of -10°C.

Space allowance/stocking density

Loss of balance on moving vehicles is a major hazard in the transport of farm animals and can lead to animals becoming severely bruised, injured or killed. This can occur from stock being thrown about the vehicle, trampled, or suffocated by other stock if unable to get up. Both over stocking and under stocking animals can directly effect their balance when roads are rough, the vehicle has poor suspension, there is a lot of stopping and starting, or the standard of driving is poor (Eldridge et al. 1984a).

Stocking density is also a variable that is most easily manipulated. The recommendations for space allowances or stocking rates based on scientific research for various classes of stock vary considerably (Grandin, 1981; Tarrant, 1990; Eldridge, 1988a; Lambooij and van Putten, 1993; Hall and Bradshaw, 1998). There are considerable differences in space allowances recommended for different classes of stock in various countries (Table 14).

Table 14
Space allowance specifications in EU and Australia

Country	*Cattle* m^2*/350kg*	*Pigs* m^2*/100kg*	*Sheep (shorn)* m^2*/26-55kg*
European Union	1.02	0.42	0.2-0.3
Australia	0.78	0.35	0.22

When livestock are over loaded in a truck there is a major risk of an animal falling down, and becoming trapped on the floor by the remaining animals 'closing over' and occupying the available standing space. A domino effect can occur, and standing animals may loose their footing by trampling on a fallen animal. Attempts to reduce transport costs by overloading are offset by injury or death losses, as well as downgrading of carcasses due to bruising. Eldridge and Winfield (1988) found that carcass bruising was higher at both low and high space allowances compared to medium space allowances (Table 15).

Table 15
Mean bruise score for whole carcasses from cattle transported at low, medium and high space allowances (Eldridge and Winfield, 1988)

Space allowance M^2*/400kg*	*Bruise score on whole carcass*
Low (0.89)	8.2
Medium (1.16)	1.9
High (1.39)	4.6

Results in a study by Lambooij and Hulsegge (1988) found that loose transport of heifers at a space allowance of 300-350 kg/m^2, was better for the animals because of the lower injury rate. When transported loose, the animals leaned on one another without injury. When dividing gates were put up between each 2 animals, they showed skin lesions from banging against the pen gates. Yet the Dutch Road Transport Act prescribes adult cows and heifers to be separated by a gate between every 2 animals when the transport lasts longer than 10 hours. Dutch transporters however, are said to transport 5-10 heifers per compartment (against the regulations) to reduce bruising (Lambooij and Hulsegge 1988). Malmfors et al. (1983) reported that the DFD incidence was lower in individually penned cattle compared to group penned cattle during transport. In this study however, the stocking rate was low in the loose range pens, which could have predisposed the stock to being thrown about in transport. However, Tarrant et al. (1992b) suggested that packing cattle tightly for mutual support and support from the pen sides, results in more bruising than allowing them sufficient space to adjust their posture and brace themselves against the movement of the vehicle.

Surveys of pig transport conditions in seven European countries showed stocking rates were most common at 0.35-39 m^2/100kg pig (Barton Gade and Christensen, 1998). The recent EU directive states that stocking rates for pigs should be at 0.42m^2/100kg pig. According to research conducted by Barton Gade and Christensen (1996; 1998) this stocking density may not be appropriate for short transport distances under Danish conditions. The incidence of skin damage in pigs was lowest at stocking rates of 0.35m^2/100kg pig, and greatest at stocking densities of 0.42 m^2/100kg pig. At lower stocking rates (0.42 m^2 and 0.5 m^2), pigs were found to have difficulty maintaining balance during transport, and there was continuous disturbance from other pigs, resulting in the pigs not laying down, even after 3 hours of transport. Warriss (1994) recommends an ideal stocking rate at 0.45m^2/100kg. This providing a slightly greater area than required for sternal recumbency and will thus ensure enough space for all animals to rest. It is important to consider that Danish transport vehicles are well ventilated, therefore higher stocking rates in warmer weather is not so detrimental to pig welfare. Also, research indicates that pigs do not lie down to rest early on in the transport process (Bradshaw et al 1996a). Therefore it is logical to use higher stocking rates on short journeys in vehicles with temperature control or in cooler environmental conditions.

However, Gispert et al. (in press) found that pigs in Spain transported at stocking densities >0.4m^2/100kg produced a better proportion of good quality meat (i.e. ultimate pH values >pH4 and <pH6). Table 16 shows the least square means of mortality during transport of two transit loading densities (<0.40m^2 and >040m^2 per pig) from a survey of 4 different abattoirs in Spain (Guárdia et al. 1996). These results indicate that when hauliers used stocking densities higher than 0.4m^2 per pig, no significant differences were observed between abattoirs. However, when the area per 100kg of pig during the transport was reduced to less than 0.4m^2, abattoir B showed the higher transport mortality compared to the other abattoirs. This is most likely due the higher stocking rates leading to poor ventilation.

Table 16
Least square means (LSM) and standard errors (SE) of mortality during transport in relation to the density of transport (<0.40 and >0.40 m^2 per pig) in five abattoirs (Guárdia et al. 1996)

	Stocking	*Density*	*m^2/pig*		
Abattoir	***<0.40 LSM***	***SE***	***>0.40 LSM***	***SE***	***Significance Level***
A	0.36^b	0.10	0.57	0.11	NS
B	0.77^a	0.09	0.04	0.26	**
C	0.15^b	0.13	0.13	0.16	NS
D	0.11^b	0.08	0.26	0.36	NS
E	0.01^b	0.15	0.00	0.14	NS

LSM with different superscripts indicate significant differences among abattoirs ($p<0.05$).
Significance level:**(0.01); NS: Not significant.

According to research conducted by Bradshaw et al. (1996d) pigs spent most of their time standing during short journeys (less than 3 hours) at stocking rates of 0.49m^2/100kg. However, Lambooij and Engel (1991) showed pigs with a stocking density of 0.45 m^2/100 kg, began to lie down after about an hour, and that most were lying after 2.5 -3 hours. This was accounted to the smoothness of the journey while the experiment by Bradshaw was reported to be rough due the use of a 4- wheel rigid chassis truck, shown to have poor vibration characteristics leading to a less comfortable ride (Randell et al. 1996).

The EC directive (L340/17) states that "the loading density for pigs of around 100kg should not exceed 235kg/m^2 (Contrary to research findings by Barton Gade and Christensen, 1996; 1998). Also "the breed, size and physical condition of the pigs may mean minimum required surface area has to be increased" and "a maximum increase of 20% may also be required depending on the meteorological conditions and journey time". A 20% increase is equivalent to a maximum stocking density of 0.510m^2 /100kg. Lambooij and van Putten (1993) found that pigs were more stressed when transported at stocking densities higher than 0.5 m^2 /100kg. The larger space allowing mixed groups of pigs to fight.

In research conducted on lambs transported within the UK for up to 24 hours (Knowles et al. 1993; 1996) and lambs exported to France on journeys lasting 34 hours (Knolwes et al. 1994c) results indicated that stocking density had a significant effect on the animals welfare. Further research conducted on the effects of stocking density on sheep welfare found that at high stocking rates i.e. 0.448m2/100kg, fewer lambs were able to lie down and rest, and these lambs had higher levels of plasma creatine kinase indicating that they were fatigued (Knolwes et al.1998). Higher stocking densities for sheep also become a welfare concern in warmer weather. At too high stocking rates hypothermia can become a problem because the increased contact between sheep increases heat exchange between individuals and at the same time limits the surface area from which heat can be dissipated (Knowles, et al. 1998). Therefore weather conditions should influence what stocking rates are used, especially for unshorn sheep. According to Hall and Bradshaw (1998), shearing wool off sheep can influence the number of sheep that can be transported on a truck by increasing it up to 25%.

Journey lengths should influence the stocking rates used on transport vehicles. It has been shown through the studies of Barton Gade and Christensen (1998), that higher stocking rates for pigs ($0.35m^2$) are practical on shorter journeys. However, longer journeys of up to 2 days, the stocking rates should be lower ($0.42m^2$) in order to allow pigs to lie down and rest (Lambooij et al. 1985).

Weather conditions, size, species and weight of livestock, animal temperament, journey duration, standard of truck driving, road conditions and type of transport facility are all factors that make it difficult to make rigid loading density recommendations for the transport of livestock. Although there is conflicting research on optimum stocking densities, there seems to be a consensus that stocking density should be such that allows animals to get back up again if they fall over, and rates should be lower in warmer weather especially in the event of no climate control. There is a lack of research in comparing different transport vehicle pen sizes and the stocking rates within each pen.

Transport duration

Scientific results discussed earlier in the report from measuring behavioural and physiological responses of livestock to the transport process prove that transport is an inherently stressful procedure for them, and under poor conditions meat quality defects are increased. However, where conditions in transport are good, long (between 15 and 24 hours) transport durations for livestock to a certain extent, can be no more stressful for livestock than short journeys (Wythes, 1994). If transport conditions are poor for livestock, even the shortest journeys can be highly stressful and result in high meat quality losses. For example, Wythes et al. (1988b) found that cows rested after transport periods of 9, 15 and 20 hours, had more bruising than those transported non stop for 36 hours and rested for the same total period. Muscle pH and tenderness values were also similar between cattle on the shortest journey and those on the longest journey. The higher bruising scores in the short transport group were contributed to the extra handling involved with loading and unloading of the animals during the rest periods.

Tarrant and Grandin (1993) suggest that dehydration and fatigue occur in cattle after 24 hours of transport to the point where any extension of this time is detrimental to the welfare and meat quality of animals. In pigs however, Warriss (1987) does not recommend transporting pigs over 21 hours with out a rest period. This is because the fasting interval in pigs over which liver glycogen is depleted to less than 10% of its normal value in the fed state is 21 hours. For a 90kg live pig, a loss of between 0.8 and 1.6kg of potential carcass yield might be expected after deprivation of food for 24 hours. This is the equivalent to the loss of value of more than 1 pig for every 100 marketed (Warriss, 1993). Long transit periods also increases the risk of pig mortality (Warriss 1993; Jarrott et al. 1982).

Much of the emptying of the stomach contents of livestock occurs in the first 5 hours of fasting. Therefore, abattoirs generally recommend farmers to fast their animals not less than 5 hours before transportation. The advantages of this for the abattoir are that the animals will be cleaner after transport with reduced faecal matter spreading on the animals body, and the empty gut contents makes removing the viscera from the carcass easier and more hygienic. Feeding pigs just before transport predisposes them to travel sickness and is therefore not recommended (Bradshaw et al. 1996c). Travel sickness being described as a combination of retching, chewing, foaming at the mouth and sniffing the air while standing (Bradshaw et al.

1996b). Gispert et al. (in press) compared the effects on stress and meat quality in pigs subjected to 3 different pre transport fasting intervals (<12, 12-18 and >18 hours). Pigs fasted between 12 and 18 hours pre-slaughter had the most optimal meat quality and lowest stress responses (Table 17).

Table 17
Stress and meat quality characteristics found in pigs fasted for different time intervals pre-transport (Modified from Gispert et al. in press)

Pre-transport fasting Interval	*Cortisol ug/100ml*	*Moderate PSE %*	*Moderate DFD %*
< 12 hours	8.4	42.8	11.1
12-18 hours	7.5	39.1	11.9
> 18hours	8.8	43.6	15.4

Although long distance transportation of pigs is undesirable, resting points for unloading and feeding and watering the animals on long trips (up to 24 hours) is not recommended (Bradshaw et al. 1996a). Pigs are stressed by loading and unloading, and are predisposed to travel sickness after feeding intervals. If the journey is smooth and uninterrupted, it is better for the pigs to continue their journey without stops (having settled down after the first 5 hours of transport) (Bradshaw et al. 1996a, b). Lambooy et al. (1985) found that by providing water continuously during at least part of a long distance journey pigs drank very small volumes. In journeys of 26-31 hours they consumed an average of only 0.651 litres per animal, and on a journey of 44 hours, less than 5.41 litres- some of which was spilled rather than drunk. It was predicted that normal consumption during transport would be around 7-20 litres per day. There was no effective influence of water provision on liveweight loss during the journeys in either study. Lambooy (1988) suggested that pigs did not drink because of stress, fatigue, lack of food, truck vibration and unfamiliarity with nipple drinkers. Continuous water provision did however reduce initial meat pH values, but other than that there appeared to be few benefits of water provision. In a study conducted by Brown et al. (1999), pigs drank and ate the most when put in lairage after 24 hours of transport compared to pigs transported for 8 and 16 hours. The pigs on the longer transport journey took much longer to settle, and the total activity recorded was double that of the other 2 groups, indicating that after longer journeys, pigs require more time to eat, drink and rest prior to slaughter.

Sheep are less likely to be stressed by long journeys than pigs (Hall and Bradshaw, 1998). This is in part because in ruminants, the rumen can hold 15-20% of the total body water and can act as a buffer against dehydration (Knolwes, 1999). Warris et al. (1987) tested the effect of transport time on carcass yield in sheep, and found that there were no significant effects of transport up to 6 hours on any body components or muscle pH. Broom et al. (1996) found that in catheterised sheep, an initial response to loading and commencement of transport was virtually extinguished within 3 hours, and for the remainder of the journey of 15 hours, stress responses were only slight. Knowles et al. (1993) also concluded that length of journey had no effect on rate of recovery when comparing lambs transported for 9 and 14 hours in northern Europe. Hall (1995) found no evidence that sheep are adversely affected by lack of water for a period of up to 48 hours, even in relatively high ambient temperatures. This is also supported by research conducted by Parrott et al. (1996). In both studies it was concluded that water balance in sheep was adversely affected if food was provided in the absence of water. Further to this in 2 separate studies by Knowles et al. (1993 and 1995), using measurements of plasma total protein, albumin and osmolality, no evidence of dehydration was found during journeys of up to 24 hours within the UK where the ambient temperature did not rise above 20^{o}C. However, studies on lambs transported through France for 24 hours in temperatures above 20^{o}C, the levels of plasma total protein, albumin and osmolality indicated that lambs did become dehydrated (Knowles et al. 1996).

With regard to resting intervals during long distance transportation (up to 24 hours), Knowles et al. (1993; 1995; 1996) found that feeding and watering lambs after 15 hours transport had slight beneficial effects in reducing live-weight loss and dehydration. After 15 hours lambs lost 6.4% live-weight, and after 24 hours they lost 7.3%, which was regained completely after 24 hours lairage. The lambs were alert and physically fit, and when offered feed and water, were primarily interested in feed, and secondarily interested in drinking, and finally resting. Other research indicates similar results (Hall et al. 1997; Parrott et al. 1998). In the study conducted by Parrott et al. (1998) sheep were rested for 1 hour after 14 hours transport, and then transported a further 17 hours, the total trip being 31 hours. Behaviour and physiological response was examined, and the results suggest lambs are better to have access to water only, and not feed. Further to this, experiments by Hall et al. (1997) have shown that a break of 1 hour is unlikely to be of any benefit to sheep on long journeys. After 14 hours of transport sheep ate but did not drink in the first hour. After 4 hours they drank, but when the vehicle began to move they did not. Hence later in the journey they were water deprived and their osmolality increased. From these studies it can be ascertained that sheep are likely to eat but not drink during short (1 hour) rest periods, contributing to dehydration. Other reports indicate that depending on the type of food offered, at least 2 hours is needed for animals to settle and drink after transport (Knowles et al. 1996) and can take up to up to 4 hours (Hall et al. 1997). Where food is provided on or off the vehicle, Broom et al. (1998) also suggests a rest period of 4 hours if sheep are to be able to drink and eat mid journey on long distance trips. Knolwes et al. (1996) kept lambs in lairage with concentrate, hay and water available for 8 hours after a 24 hour journey. After a further 10 hour transport, the lambs were in a better state of recovery than they had been at the end of the first 24 hours of transport. In these circumstances an eight hour lairage provided the opportunity for substantial recovery. However, shorter rest periods do not seem to be of any real benefit, and as shown in the study by Parrott et al. (1998), short rest periods can be detrimental to animal welfare.

Similar studies of the effects of long distance transport on the physiology and behaviour of cattle have been conducted. The most recent by Knowles et al. (1999) who investigated the effects of transport periods of 14, 21, 26 and 31 hours, including a stop for a rest and drink on the lorry after 14 hours. Physiological measurements indicated that a journey lasting 31 hours was not excessively demanding, but many of the animals chose to lie down after approximately 24 hours. Similar results were found in a study by Tarrant et al. (1992a) when during the last 4 to 8 hours of a 24 hour truck journey, several of the cattle lay down. The animals that lay down in the study by Knowles, had higher plasma cortisol levels than those that remained standing. This is probably because unlike smaller animals, it is more difficult for cattle to lie down because of their weight, and once down it is likely that they are caused discomfort from the jolting of the lorry. It was also found that the majority of cattle chose to drink (58%) during the rest stop, which differs from the results conducted on sheep by Hall et al. (1997). There were consistent differences between the amount of drinking on the two types of lorries (cattle transported on double deck lorries drank significantly less), thus indicating that the conditions of travel and the circumstances under which water is offered affects how many and to what extent animals will drink. For animals too unsettled to drink the journey is prolonged one hour and according to Knowles et al. (1999) a one- hour rest stop is insufficient for any real recovery.

In a study on long distance transport (Lapland to Finland), distance had no significant effect on DFD occurrence in cattle (Honkavaara and Kortesniemi, 1994). Eldridge et al. (1988a) found that in cattle transported for distances up to 550 kilometres, there was little influence on heart rate levels when compared to cattle transported short distances. Sinclair et al. (1992) also found that cattle transported longer distances appeared no more stressed than when transported short distances. In contrast, Jones and Tong (1990) reported a linear relationship with increasing distance and the percentage of high pH carcasses in cattle. With 0.8, 0.9, and 1.0 % for distances of less than 100km, 101-300 km and more than 300km respectively. Möller et al. (1994) reported that in Sweden, longer transport times increased pH levels in beef relative to the increased travel times from 1-6 hours. Gebresenbet and Eriksson (1998) also reported that cattle transported on longer trips (>3 hours) had higher pH levels than cattle transported under 3 hours. However, in this experiment cattle transported over the longer distances also experienced rougher road surfaces than those on shorter trips. Jarvis et al. (1995) found that cattle sold through the market system showed more evidence of dehydration at slaughter than cattle transported short distances to slaughter. It is suggested that providing water in sale yards and in lairage would prevent such dehydration occurring.

Morbidity (unhealthy, sick) and mortality is higher among young calves (less than one month) during the first few weeks after they have been transported long distances, compared to 6 month old calves (Cole et al. 1988). Knowles et al. (1997) completed studies on the transportation of calves less than 1 month old. The calves were transported at different trip duration, and fed and watered at different intervals. The physiological response to food and water deprivation over 24 hours was similar to that observed in adult cattle. Unloading and loading calves in order to feed electrolytes after 8 hours over a 24-hour journey was found to cause increased heart rates and cortisol levels in the calves. Mormede et al. (1982) looked at the effects of journey length on 4 to 32 day old calves, and found that numerous physiological measurements were modified by transport, but journey duration had little effect. However, increased length of journey substantially increased the susceptibility of the calves to respiratory diseases. The results of the above studies suggest that although long distance transport of calves is undesirable, there are few benefits of mid way feeding on a 24 hour journey if it is required to unload animals for feeding. It appears that it would be better to get the calves to their final destination as quickly as possible for journeys of less than 24 hours. Stops for feed at commercial staging posts would also greatly increase the risk and spread of infection, both between and within different truckloads of calves.

Friend et al. (1998) studied the stress response of horses transported long distance in a commercial truck, and concluded that tame horses in good condition and deprived of food and water during the journey, can be transported for up to 24 hours before dehydration and fatigue become serious. Many slaughter horses are not tame, and will be more stressed by transportation than trained horses, and according to Friend et al. (1998), they are unlikely to settle and drink or feed while on a truck. Mars et al. (1992) found that after transport horses were reluctant to drink in an unfamiliar environment. It was therefore concluded that unloading slaughter horses or livestock not used to being handled in order for them to drink and eat, may cause more stress than rest to the animals.

The question whether animals should be lairaged mid transport for rest periods and for how long, and under what conditions is problematic. As mentioned earlier full recovery from periods of transport has been shown to take various lengths of time. For animals not used to being handled, unloading mid way for a rest period may actually cause more stress on the animals than allowing them to continue and get the journey over with. However, if the weather conditions are hot, and the transport vehicle has no adequate ventilation, or the vehicle is overstocked or travelling on rough roads, mid journey resting periods may well save the lives of many animals. Long transport periods for livestock with out rest periods should only ever be permitted under the following conditions:

- all livestock are in good, healthy condition and are old enough to cope with transport stress;
- the transport vehicle is in good repair with good suspension and has good ventilation characteristics;
- the stocking rates are such that all animals can lie down and get up;
- all livestock are able to be inspected on a regular basis;
- the truck is driven with care;
- the route of travel is along smooth roads.

It is important to note that research conducted on the effect of transport duration on animals is generally under good transport conditions. Therefore results do not necessarily reflect industry practice. In situations where transport conditions are poor, the above results become irrelevant.

Preslaughter lairage

After transport to an abattoir, livestock are usually kept in lairage for a period before being slaughtered. The main purpose of lairage is to maintain a reservoir of animals so that the processing line in the abattoir can operate at a more or less constant speed irrespective of variations in the delivery of livestock. A second function is to allow animals to recover from the stressful effects of transport in regard to meat quality and for better animal welfare (Warriss et al. 1992). However, there is a question whether animals should be lairaged and under what conditions.

European studies suggest that resting periods in cattle should be kept as short as possible (Fabiansson et al. 1984; Franc et al. 1988). This contradicts some Australian research which has shown that rest in cattle reduces muscle pH (Wythes et al, 1988a, b). However, rest effects on muscle properties cannot be considered in isolation, particularly where cattle are transported medium to long distances to abattoirs in hot conditions. Under these circumstances, it is evident that cattle need time to at least drink and re-hydrate carcass tissues before slaughter. Cattle that have access to water after transportation for 27 hours had 6% heavier carcasses than those denied water (Wythes, et al. 1983). It was found that cattle rested 4 days after a 1300km journey to slaughter, yielded a lower proportion of dark cutting carcasses (ultimate pH>5.8), than did animals rested only 2 days (Table 18) (Shorthose, 1988). Studies in sheep found similar results (Shorthose, 1977).

Table 18
Effect of resting/feeding on ultimate meat pH in M.longisimus dorsi (LD) in steers transported 1300km (Shorthose, 1988)

	Time rested			
	2 days		***4 days***	
Time on water	1 day	1 day	3 days	3 days
Time on feed	-	1 day	2 days	3 days
% of LD pH values (>5.8)	40	50	10	5
Average LD pH	5.84	5.93	5.72	5.64

On the other hand too much rest prolongs the time from farm to slaughter. Resting cattle in strange environments must be done without imposing even greater stress. There are situations where some cattle in a group will not eat or drink during resting periods. However general observations have shown that if cattle are not disturbed while resting, they will drink from unfamiliar troughs (Wythes, et al.1983). There is another problem to consider when resting and feeding ruminants in lairage. In the live animal, pre-slaughter fasting causes a reduction in rumen fermentation and less volatile fatty acids are produced. As a result the pH of the rumen contents rise and allows any *Escherichia coli* or *Salmonella*, spp that are present in the rumen to multiply (Gregory, 1998). According to Eldridge et al. (1986) giving fasted ruminants feed during lairage encourages further multiplication of pathogenic bacteria in the gut, and the longer the animals are held before slaughter, the greater their chance of infection. Where pigs are excreting *Salmonella*, up to 20% of the *Salmonella* free pigs are thought to become infected during transport and lairage (Gregory, 1998).

Under European conditions, it has been proposed by Barton Gade (1993a) that feeding cattle at arrival at the abattoir after transportation is not feasible as a method of preventing DFD. This is because it takes more than 2-3 days for glycogen concentrations to return to normal. Larcourt and Tarrant (1985) agree with this, and they found it took 3-7 days for muscle glycogen concentrations to return to normal in bulls that were experimentally lairaged and grouped with unfamiliar bulls for 5 hours.

Atkinson (1992) found that resting behaviour and rehydration status in 7-15 day old calves after transport from farms and markets to a lairage facility, returned to values similar to non transported calves after 10 hours in lairage. However in this report it was not mentioned the distances the calves had previously been transported. Younger calves in this experiment were found to be more stressed by transportation than older calves. Kilgour and Dalton (1983) found that calves spend 20 out of 24 hours resting during their early life, indicating that transport must be exhausting for them. Therefore a lairage period is necessary for them to recover after transport.

In practice lairage times for pigs vary widely from less than 1 hour to twenty or more hours (Warriss, 1993), and are most often suited in co-ordinance with supply of the abattoir slaughter line. Spencer et al. (1984) showed that road transport increased the plasma cortisol concentration in pigs, but after holding animals a few hours before slaughter, concentrations were back to pre-transport levels. The effect of pre-slaughter lairage in pigs for less than 1 hour, 3 hours or overnight was studied. Longer lairage reduced stress levels based on blood concentrations of cortisol and lactate. It also reduced the levels of PSE but increased the prevalence of DFD (Warriss, 1998). Gispert et al. (in press) found similar results, and in their study as lairage time increased (> 9 hours), the proportion of DFD carcasses increased. Table 19 outlines the effect of different lairage times on carcass characteristics. In this study longer lairage times correlated with progressively increased skin damage caused by fighting between unfamiliar pigs. Similar results were found by Geverink et al. (1998) where skin damage in pigs increased proportionally to the time pigs spent in lairage if they were mixed, and also increased if pigs were driven harshly up to slaughter. Gevernick et al. (1998) concluded that it could be better to slaughter pigs immediately upon arrival at the abattoirs. However, Santos et al. (1997) found when comparing pigs slaughtered directly on arrival to the abattoirs or lairaged for 2-3 hours, that direct slaughter lead to poorer meat quality than those killed after 2-3 hours of resting time. This is in agreement with the overall conclusion by Warriss et al. (1992). A period of rest between 1 and 3 hours in lairage allowed physiological measurements of stress to reduce and meat quality was optimised. Santos et al. (1997) however, recommended direct slaughter of pigs in situations of no temperature control in the lairage system when environmental conditions are hot and humid (30°C or more).

Table 19
The effect of lairage time on the frequency (%) of carcasses with different characteristics (Modified from Warris et al. 1995)

	Lairage time		
Carcass traits	***<1 hour***	***3 hours***	***overnight***
Moderate/Severe Skin blemish	5.3	8.8	17.8
PSE ≥ 5	41	36.9	44.3
DFD LD ≥ 5.8	1.2	6.2	6.6
SM ≥ 6.0	2.3	3.5	7.8

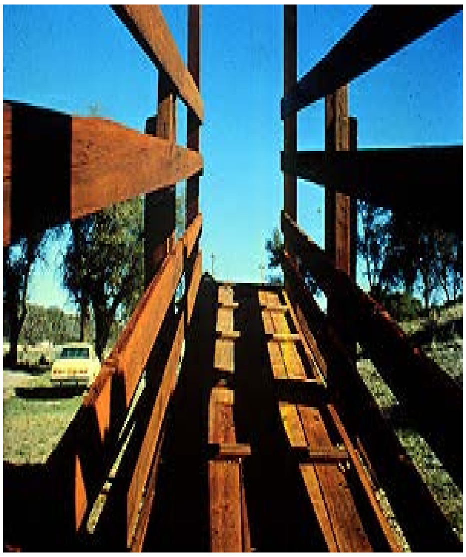
Stress immediately before slaughter at the abattoirs can override the advantages resulting from an effective resting period. Geverink et al. (1996) found that skin blemishes were highest in pigs held in lairage with the highest stocking density. Pre-slaughter stress conditions that abattoirs should aim to avoid include aggressive handling from stock-persons, regrouping of animals, overstocking in holding pens, high noise levels, badly designed facilities, poor ventilation and stoppages or interruptions in the flow of animals through races leading into the killing box (Wythes, 1994). By basing lairage times according to the stress and transport duration imposed on the animals, ensuring lairage pens are clean, well drained and designed, and keeping the lairage period quiet, lairage will be beneficial to meat quality in most livestock.

Design of animal handling and transport facilities

It is thought that the loading and unloading facilities in many countries are inadequately designed for the efficient and low stress movement of livestock (Lapworth, 1990). The movement of livestock on and off trucks can be enhanced with equipment designed to minimise fear provocation in livestock and better fit their sensory preferences. Design features such as circular yards, curved lane ways, races with solid or semi solid fences and long tapering entrances, should exploit the vision, circling and follow the leader habits of cattle and sheep. Dead ends, sharp corners, and obvious lighting contrasts should be avoided (Ewbank, 1993; Grandin, 1993a). Pigs, sheep and cattle have a tendency to move from a dimly lit area to a more brightly lit area, provided the light is not glaring into their eyes (Grandin, 1989a, van Putten and Elshof, 1978). Pigs raised indoors will often refuse to approach sunlight. A totally enclosed loading area will help prevent pigs balking in this situation.

Moving objects and people seen through the sides of a loading race can frighten livestock, and outer walls of loading races that block all vision to outside distractions are far more effective in controlling animal movement. Figure 15 demonstrates photographs of good and bad race designs for loading cattle, and Figure 16 for sheep.

Circular crowd pens and curved single file races such as shown in figure 17, can reduce the time required to move cattle on to trucks by up to 50% (Vowles and Hollier, 1982). They prevent animals from seeing what is at the other end of the chute until almost at the end (Grandin, 1989a).



Good loading race design *Poor loading race design*

Figure 15. *Examples of good and bad designs of cattle loading races***.**

Good sheep loading race design *Poor sheep loading race design*

Figure 16. *Examples of good and bad sheep loading race designs.*

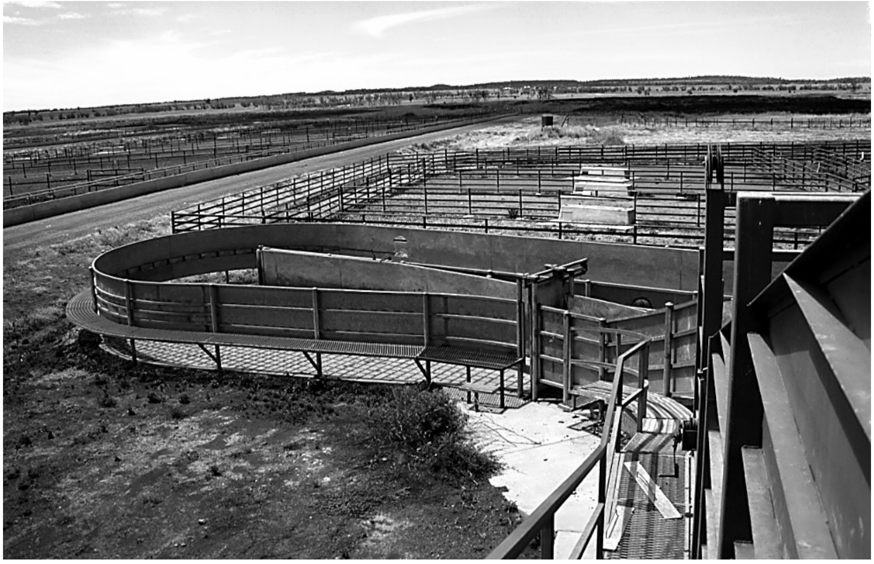


Figure 17. *Curved loading race system at an Australian feedlot.*

Open wire or rail fences are an advantage wherever the interaction between neighbouring cattle will assist the flow of animals from one yard to the next and along lane-ways.

Jarvis et al. 1995 found that the flow of cattle down a race was frequently disrupted because it was wider than the width of one animal, allowing cattle to turn around and create handling problems. An animal standing in a forcing pen must also be able to see a minimum of 2-3 body lengths up the single file race before it curves. An abattoir in Australia found lower bruising rates in cattle bought from saleyards that were known to have well designed handling facilities and good stockmanship compared to poorly designed and managed saleyards (Wythes et al. 1985b). Non slip flooring is essential to the welfare of livestock. Falls and slips can be reduced if smooth surfaces are textured or grooved, and well drained.

In the transportation of livestock, it is during truck loading and unloading that often causes most stress to the animal (Trunkfield and Broom, 1990, Knowles, 1995; van Putten and Elshof, 1978; Augustini and Fischer, 1982; Hall and Bradshaw, 1998). Animals may fall, particularly on slippery ground, and there may be excessive use of sticks or electric prodders by stockmen (Tennessen et al. 1985). A sharp rise in cortisol levels in calves was found in the first 2 hours of transport (Kent and Ewbank, 1983), while levels stabilised on longer journeys, suggesting that loading caused the stress. In the marketing of sheep, the most potentially bruising events occurred during loading (Jarvis and Cockram, 1995). Broom et al. (1996)

found that the major stress imposed on sheep undergoing a journey of 15 hours was the herding and loading at the start. Parrott et al. (1998) compared 2 loading strategies (hydraulic lift versus conventional ramp) for loading sheep on to a truck, and found the effects of the 2 methods of loading similar. However, in this project, the sample size was only 3 sheep for each loading procedure, a sample size not realistic of normal loading numbers for slaughter sheep. Bradshaw et al. (1996a) found pigs on an 8-hour journey had highest plasma cortisol concentrations during loading, which declined after 5 hours to near control (pre-transport) levels. They also concluded that when loading and unloading facilities are of poor quality and design, the effects on pig welfare and meat quality are highly detrimental.

Since loading and unloading contribute a lot of stress in animal handling, it is very important to have adequately designed facilities. In Denmark and Sweden, most pig transport trucks are fitted with hydraulic tailgates, which are the most ideal loading facility for pigs. However, if it is necessary to use loading ramps, Grandin, (1989a) recommends ramp angles at no more than 20°. Warriss et al. (1990a) demonstrated that the steeper the ramp, the longer it took pigs to move along it (Figure 18). It was also shown that when a narrow (15cm) cleat (foot support) spacing was used, pigs could climb a slope of 35° rather efficiently. However, at a wide (30cm) spacing they took almost twice as long to climb the same ramp. This has implications for vehicles used for both cattle and pigs.

Kenny and Tarrant (1987) found loading ramps did not present a major obstacle for cattle, and loading/unloading was accomplished without difficulty. However, the animals used in this experiment were intensively reared 2 year old Friesian steers, which were likely to have been quiet and transported previously as young calves. Even though cattle have no problem to negotiate different ramp angles (Eldridge et al. 1986), ramps with a level landing apron at truck height, and a slope of less than 20 degrees aids smoother movement of cattle on and off trucks and minimises injury (Lapworth, 1985).

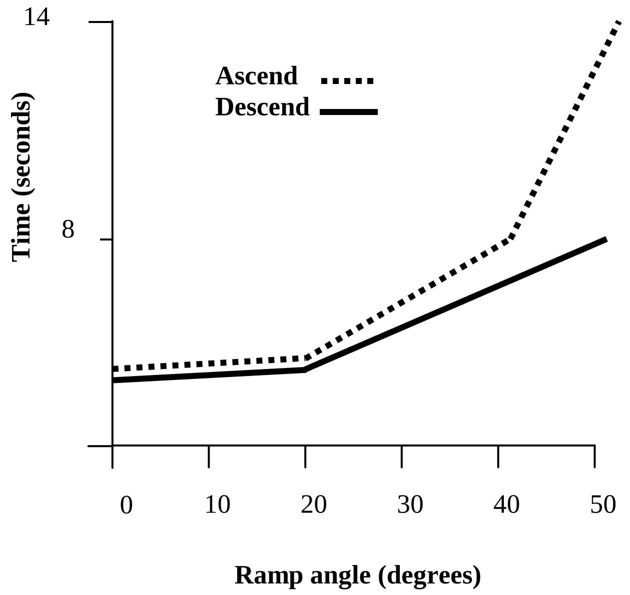


Figure 18. *Time taken by pigs to ascend and descend ramps of different slope angles (Warriss et al. 1991).*

Bremner et al. (1992) found that calves moved more freely and were less stressed and physically injured by being unloaded onto level, or slightly upwardly sloping ramps. Many calves were unable to remain upright at ramps of 12°. Eldridge et al. (1988a) found that cattle aged more than 1 year slipped less often on a ramp with a gradient of 11.3° compared with 18.3°.

During transport, particularly on rough and unsurfaced roads, the transmission of the vehicle's floor vibration to the animal probably creates uncomfortable conditions by causing displacement of the centre of gravity of an animal, resulting in body disturbances (Randell, 1992). Truck vibrations can significantly contribute to travel sickness in pigs. There is very little research available on studying the effects of different vibration frequencies on the welfare of animals. However, by installing pneumatic suspension vehicle vibration can be reduced (Tarrant, 1990). The suspension must be kept in good repair because a damaged pneumatic suspension can produce higher vibration than a vehicle with leaf springs (Singh, 1991). Meischke et al. (1974) found that cattle transported on solid body trucks had heavier bruising than those travelling on articulated semi-trailers. In a study by Honkavaara and Kortesniemi (1994), temperatures below -30°, made the springs of one of the transport trailers stiff, influencing the very heavy carcass damage found in those animals compared to animals transported in trailers where the springs were adequately functioning. They also found greater carcass bruising in cattle transported in trailers than those transported in fixed truck carriages. A comparison of 4 pig trucks showed that twin-axle trailers (often used by farmers in Europe to transport about 10 pigs) are likely to produce the worst types of vibration pattern. Large fixed-body transporters with air suspension provided the smoothest journeys for livestock, then medium and small sized fixed-body trucks (Randell et al. 1996). In a study conducted by Barton Gade et al. (1996), pigs transported on the lower tier of a double tiered transport truck were found to have elevated cortisol levels, more skin damage, and a tendency to more DFD meat than pigs transported on the upper deck. It was hypothesised that tier effects may be due to a combination of these pigs experiencing more vibration and less ventilation than pigs in other parts of the truck.

It has been suggested that transporting horses facing away from the direction of travel is less stressful than transporting them facing the direction of travel (Creiger, 1982). Other studies reveal that tying horses facing away from the direction of travel improved their ability to maintain balance (Clarke et al. 1993; Waran, 1993). However, these studies do not pertain to loose horses transported in groups, and this is an area that requires more research.

Upgrading and maintaining animal handling and transport facilities should be a priority for animal welfare reasons (Lapworth, 1987). Trucks should have non-slip flooring, smooth walls, wide loading gates, stable and smooth internal partitions, and no protruding bolts, gate latches or other objects. Unfortunately, improvements in handling facilities are costly, and it is often difficult for companies to quantify the benefits that may occur with improvements, especially as the results may not be immediately apparent. In Denmark there has been a great deal of work conducted on designing trucks, unloading, lairage and abattoir systems to minimise stress and maximise meat quality in pigs. One highly developed abattoir moves pigs through the plant by way of a fully automatic gate system, moving pigs in groups of 15 corresponding to the compartment size of most trucks. The system has been designed to utilise pig behaviour at all stages to reduce the need for force as far as possible. A push hoist-gate automatically moves behind the pigs until a point is reached that allows a flap gate to close. The push-hoist gate is then raised and moved back to collect the next 15 pigs. This system was compared to an older more traditional system and there were large differences in meat quality (Table

20). The slaughter rate in this factory has increased and runs at 800 pigs per hour. Since installing the improved handling designs, mortality has also fallen 30% (Barton Gade, 1993a). This is proof in itself that improvements in design of handling facilities is not only better for animal welfare, but increases meat quality.

Table 20
Incidence of unacceptable meat quality before and after improvements in abattoir design (Modified from Barton Gade, 1993)

Description			*Old System (60 pigs)*	*New System (15 pigs)*
%PSE	*b. femoris*	*probe>100*	2.7	4.0
	I.dorsi	*probe>80*	1.9	1.4
	b. femoris	*pH > 6.1*	2.1	1.3
% DFD	*I. dorsi*	*pH > 6.1*	4.5	2.5
	s. capitis	*pH > 6.3*	19.9	8.3
		Ham	17.7	3.9
% skin damage		*middle*	21.3	3.9
		shoulder	38.2	16.1
		I. dorsi	3.8	0.6
		b. femoris	1.3	0.0
% blood splashing		*semimembr.*	3.7	0.0
		Quadrceps	0.8	0.0

A DISCUSSION OF FARM ANIMAL TRANSPORT IN THE EU AND OTHER COUNTRIES

Figure 19 outlines factors that effect animal transport in general throughout the EU and Australia.

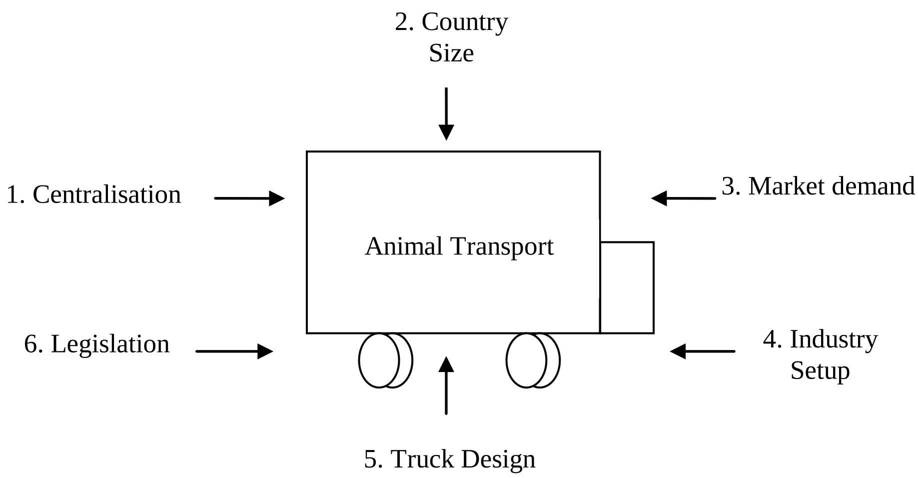


Figure 19. *Factors effecting animal transport*

<u>Centralisation</u>

Around the world millions of live animals are transported by road from farms to slaughter, either directly, or through auction centres or centralised collection points. Within the European Union, the transport of live animals by road is the most economically viable system of transporting animals (FAWC, 1991). Although animals should be slaughtered as near as possible to their farm of origin, the expansion of the EU membership and the emergence of a Single European Market, will mean a progressive intensification of the movement of live animals.

Industry rationalisation has caused the number of abattoirs in Sweden to halve in the last 20 years with 8 main abattoirs closing, leaving only 5 large scale abattoirs operating (Gebresenbet, 1998). In Sweden, in the Uppsala area alone, approximately 50,000 tonnes of live animals are transported approximately 130,000km yearly from farms to abattoirs (Gebrensenbet and Eriksson, 1998). While the production and volume and transport of meat is increasing in Sweden, the number of actual farms are decreasing (Gebresenbet, 1999). This centralisation effect seems to be occurring in many other countries. In the UK, more than half the number of slaughterhouses are operating than were in 1969, when over 2000 were recorded. The reduction in numbers has almost entirely occurred in abattoirs with lower throughputs. The larger abattoirs are increasing throughput, and some 78% of total beef slaughtered in the UK are at high throughput rates i.e. annual throughput of over 20,000 cattle units slaughtered annually (FAWC, 1985). In southern Australia, many small abattoirs have closed and one of the larger pig abattoirs have recently doubled pig killing rates and are now processing up to 4500 pigs per day (350 pigs/hour) compared to 2000 pigs a few years ago (Herbert, 2000). In larger pig abattoirs in USA slaughter rates are up to 1100 pigs per hour (Gregory, 1998). The consequences of centralisation of abattoirs and intensification of processing in the abattoirs, are that animals must be transported further distances, and are pressured by handlers that need to get the animals to load and unload. The animals are then pushed up to the slaughter process as quickly as possible to keep up with the production line. These factors often contribute to stress and decreased animal welfare.

Country size

Appendix 1 demonstrates statistics on land area, and meat production in different countries. From this information it is possible to get a picture of the level of live animal transport in these countries. In Australia and USA for instance, huge amounts of livestock are transported over long distances and duration, because of the sheer size of the countries, and the amount of livestock produced. If you compare Australian statistics to that of Denmark, Australia has a land size of 7,682, 300 square kilometres, with road systems joining the north to south over 3, 700 kilometres, and east to west, 4,000 kilometres. The country is one of the most sparsely populated, with farms spread out over the continent, with extensive beef production as one of the major livestock industries. Due to this and the centralisation of abattoirs, livestock can be transported in northern Australia for up to 8 days, or in southern states up to 3-4 days (Wythes et al. 1989). In contrast, Denmark has a total land area of 43, 094 square kilometres, with an intensive pig production as its primary livestock production. Transport distances for live animals are therefore relatively short. Ramsgaard Jenson

(1996) states that most abattoirs are within 100kms of any farm in Denmark, and average transport times are around 1½hours (Barton Gade, 1994). In Australia trucks can generally get a full load of animals from only 1 or 2 farm pickups. With the main highway links across Australia, long distance transport for livestock can be smooth and uninterrupted. In fact there are highways for truck use only, and livestock trucks with up to 4 or 5 trailers of stock, which are known as road trains, are able to transport stock smoothly and efficiently with little interruption. In many countries in Europe, many farms are small and located where road access may be narrow, winding or rough. Livestock may only travel 6-7 hours, but they have to endure a lot of stop starting and disturbance while the truck travels to different farms to pick up and fill the truck. Gebresenbet and Eriksson (1998) set up an experiment to observe factors under typical Swedish commercial slaughter animal transport. A truck collected from 8 different farms, 5 cows from each farm that were dispersed over an area of about 458 kilometres taking up to 6 hours. Another issue that effects the duration of livestock transport is the use of hormones to synchronise breeding cycles in livestock. The use permits a concentrated calving or lambing, which means that on farms where this is done, the animals are generally ready for slaughter at the same time. In countries such as Sweden, the use of hormones to control breeding is forbidden (Animal Protection Act 1988, Sweden). Therefore, on dairy farms calvings are spread out and each farm may have only 2 or 3 calves ready for market at a time. The welfare consequences are that the calves are transported with unfamiliar cohorts, and not in rearing groups and transport times are extended.

The size of the country also effects the intensity or extensity of livestock production. This is relevant in that it influences the temperament of the livestock being handled and transported. This is especially so for cattle. European farms tend to be more intensified and animals are in regular close human contact. In Sweden and Denmark for example, most livestock are kept indoors for at least some part of the winter months and cows are individually tethered, or in a loose housing system. Most animals are not castrated, and in Denmark steers constitute as little as 1 % of the total number of cattle slaughtered (Ramsgaard Jenson, 1996). Animals in this environment may well be quieter to handle than cattle raised under extensive conditions, but due to their confinement they are less able to cope with the physical exertion of transport. The transport of bulls also necessitates single pen transport and lairage to prevent DFD.

Market demand

The general livestock trade in different countries often necessitates animals to be transported over long distances. For example there is a substantial transport of calves (6 months or less) throughout the European Community both within and between countries (Trunkfield and Broom, 1990). The UK exports many thousands of calves to the European Continent to help clear local markets and supply foreign calf rearers who can meet the demand for veal which is not present in the UK. Many of these calves are just over one week old, and are sold through an auction system to be further sold on to Italy's veal trade, and are submitted to transport durations of 24 hours or more (Knowles, 1995).

Veal production is a lucrative trade for many countries, and although there are animal welfare concerns related to the commercial processing of such young undeveloped animals, so far any attempts to ban the trade have proven unsuccessful, especially the production of white veal. Most of the white veal is produced in France where it is highly priced in the restaurant trade. For the veal to be white, calves must have low myoglobin levels in their muscles. This is achieved by feeding calves a low-iron milk substitute and confining them in crates or narrow pens so that they do not exercise. This causes huge welfare problems for the calves in that they are not physically able to withstand transport to the abattoir because they may never have walked before, and are weakened from anaemia (Gregory, 1998). Calves also experience trauma from suddenly being taken out of confinement and mixed with other animals. As mentioned earlier Trunkfield et al. (1991) demonstrated that crate reared calves are more stressed by transport and handling than group reared calves. In Victoria a small state of Australia, 700,000 bobby calves (a by-product of the dairy industry) were transported and processed (Hides, 1998). These calves are usually 4-5 days old when sent from the farm to collection centres and then further transported to slaughter. The main welfare concerns for the bobby calf trade includes separation from mother, inconsiderate handling, and inadequate feeding leading to preslaughter dehydration and starvation. Calves are difficult to move due to their immaturity, and truck drivers under pressure to complete a contract can often become impatient, and use excessive physical force and electric prodder use. The animal is of low value (price range in 1998 was A$6-$9 per head) therefore any damage or death is of no great consequence to the transport operator or farmer (Hides, 1998). Approximately 20% of bobby calves have been through a saleyard and auctioned before transport to abattoirs (Hides, 1998). In peak season, on average, semi-trailers with 2 or more decks can carry 140 calves per deck. The decks are usually uncovered, and bottom decks receive the effluent from calves above. The State Agriculture Departments have developed educational material for farmers and transporters on the welfare requirements and care of calves when being handled, marketed and transported. Inspectors survey collection centres for bobby calves, and any calves that are found suffering are euthanasia, and the farmer sent a warning letter for breaching regulations under the Prevention of Cruelty to Animals Act. However, there are a substantial number of calves that are found unfit for sale, and in fact a survey in Victoria in 1996 at collection centres and abattoirs, found that 14% of calves were too young to be sold i.e. they had wet umbilical cords (Hides, 1998).

In Australia it is legal to induce dairy cows to calve for management reasons. Induced calves are undeveloped when they are born, and although they can be legally sold at 4 days old, they are very immature in behavioural development. They react very little to external stimuli, and are therefore even harder to load on to transport vehicles than normal bobby calves. When there is a depressed market for bobby calves, farmers opt to send them to the knackery for pet food production. There have been problems in the Victorian dairy industry where farmers have dumped induced calves at the farm gate, awaiting a knackery truck to collect them. The problem with this is that the calves are left at the farm gate alive until the knackery truck puts them down.

According to Warriss (1996), for most pigs transported in the European Community, the journey to slaughter lasts less than 3 hours. Barton-Gade and Christensen (1996) also found that in surveys of pig transport conditions in EU countries, most trips were less than 2 hours duration, with an average distance of 100km. However, there is an extensive export trade in live pigs from The Netherlands to southern European countries such as Italy. These pigs can be in transit for 2 or 3 days (Lambooij, 1988). According to Christensen et al (1994) approximately 7 million pigs are exported within the European Union annually.

The majority of journey lengths for sheep destined to commercial abattoirs in Europe are thought to be relatively short (Knowles et al. 1994c). A survey by Warris et al. (1990b) found that journey lengths for slaughter sheep in the UK are generally between 1-19 hours, with most trips (94%) around 10 hours or less. Fifty percent of lambs were found to be transported less than 120km to slaughter, taking up to 4 hours, and 75%

travelled less than 300kms, taking up to 6 hours. However, these times did not include the animals' transport to auction, through which, it was estimated 70% of the lambs would have past (Knolwes, 1998). In an earlier survey of 120,000 sheep killed in 2 slaughter plants, 1/3 were killed within 12 hours of leaving the farm, more than 45% were slaughtered after a total time greater than 18 hours, and nearly 1/4 after 24 hours (Warriss et al. 1987). However, animals transported in the export trade travel much longer distances. In the UK alone, approximately three-quarters of a million sheep were exported from the UK to other EU countries (Knowles et al. 1994c), the longest journeys being those to southern France varying in duration from 18 to 24 hours. The number of live lambs exported from the UK has also increased from 0.2 to 1.1 million between 1982 and 1995 (Knolwes et al. 1996). Many of the exported lambs are subjected to further transportation after the sea crossing to other countries within the EU. Table 21 summarises the minimum, maximum and average journey times, time without feeding, and distance travelled for sheep exported from the UK. There have been attempts to ban the export trade of live animals from the UK by political parties, however under EU rules, these parties have no legal scope to ban exports (Vet Record, 1998).

Table 21

Summary of the characteristics of 36 journeys made by sheep exported from the UK by road that were followed by the RSPCA during the period from 1985 to 1990 (cited from Knolwes, 1998)

Characteristic	***Minimum***	***Maximum***	***Mean***
Journey time (h)	6.7	36	19.2
Time without feed (h)	7.7	35.5	20.1
Distance (miles)	74.4	799.5	470.0

In Australia, sheep and lambs are often in transport and deprived of food and water for 1 to 2 days before slaughter (Morris, 1994). Depending on the market demand, sheep and cattle can be road transported from the most northern states to the most southern states or from east to west and vice versa, covering a distance ranging from 2000-4000 kilometres. In Northern Australia, slaughter cattle can be in transit often for up to 11 days when sold at saleyards and up to 8 days when they go directly to an abattoir. In the southern states periods of 3-4 days in transit are common (Wythes et al. 1989).

Even though Australia is an isolated country, there is a great demand for live animal exports to the Middle East and Southeast Asia. Sheep destined to the export trade are first road transported from all over Australia to sea ports in southern, western and northern Australia where they are loaded on to ships and transported further for 3 or more weeks. In 1999, approximately 5.8 million live sheep were exported at a value of 255 million A$. Each vessel typically holds around 60 thousand sheep. Eight million cattle were shipped live to Southeast Asia at a value of 330 million A$ (ABS, 1998). These live animal exports are the largest in the world (Appendix 1). Unfortunately this trade also experiences the highest mortality rates of any other livestock transport system. Strangely, there are few regulations protecting the welfare of these animals while in transport. There is pressure from RSPCA and a few animal welfare organisations to regulate this lucrative trade, however, little has been done to date to improve conditions or regulations in this area (RSPCA, 1999).

In countries such as the UK, USA and Australia, a common way of selling slaughter stock is by public auction in saleyards. Public saleyards provide a central place for farmers to offer for sale their livestock, and bidders provide competitive buying prices. Animals can be presented for sale in a central pen surrounded by the bidders and spectators. In Australia it is more common to have animals in yards in a saleyard complex, where classes of stock of similar weight are drafted and sorted into pens. The auctioneer is standing above the animals on an overhead walkway, walking along to each pen auctioning each group of animals. A stock person also gets into each pen and moves the animals around for buyers to get a better look at them. Up to 6000 head of cattle can be sold per week through one saleyard in southern Australia during springtime (Turner, 1998). Sometimes cattle are sold through more than one saleyard by dealers. For example prices in southern Australia may be low due to a flooded market, therefore dealers will travel around buying cheap animals at different sales buying enough cattle or sheep to fill a truckload. These animals are then transported north (over 24 hours) to be sold in areas where prices are much higher due to drought conditions for example. Lapworth et al. (1982) found that cattle from as little as within 150 km of a major saleyard could be without water for up to 33 hours and some for as long as 55 hours. Most of these cattle did not have the opportunity to drink between arrival at the sale yards and weighing. As mentioned earlier, saleyard selling necessitates extra handling, loading, transport and fasting and this causes more stress on animals and can lower meat quality compared to animals consigned direct to slaughter. In Australia approximately 40% of livestock are sold through the saleyard system (ABS, 1998). In the UK the most recent figures state that 38% of cattle and 49% of sheep were sold through saleyards (MAFF, 2000). In Denmark, Ramsgaard Jensen, (1996) states that 26% of cattle are sold through the saleyard system and 74% are sent directly to abattoirs.

No data could be found on the transport of cull animals, either on numbers or industry practices. According to the UK FAWC, it is an area in animal transport that requires particular attention. Especially now, when abattoirs are becoming centralised, and transport distances for livestock are increasing. Using data from a survey of disposal rates in UK dairy herds, the average culling rate was 22% of every herd annually. Nearly 4% were culled for reasons of mastitis infection and 1.7% for lameness (Whitaker et al. 2000). This suggests that there is a substantial number of cull cattle that are injured or sick being transported every year. In Australia, there are many animals that suffer during transport, because they are transported sick or injured. Abattoirs will only take live animals, and pay more than a knackery, so rather than getting the knackery to humanely destroy an injured or diseased animal, the farmer prefers to send the animal alive to the abattoir, and get more money for it. There are also special live auction sales for cull livestock. Generally these cull stock are simply at the end of their productive lives and are suitable to transport, however many have injuries and diseases that render them ill equipped to cope with the rigours of marketing and transport. The farmer has the opportunity to make an extra dollar from competing meat buyers sourcing cheap livestock for the pet meat processing market.

Industry setup

The structure of the market and industry set-up effects standards of farm animal transport in different countries. For example, in Denmark and Sweden, the industries are vertically integrated, consisting of producer-owned slaughter plant co-operatives (Barton Gade, 1992; Grahn, 1998). Producers are paid according to warm slaughter weight and an objectively measured lean meat percentage. Any losses incurred in transport are in part paid for by the farmer, abattoir and transport company, giving incentive for quality control for all parties involved with transporting animals from farm gate to slaughter. Thus in contrast to other countries, factory economy does have consequences for producers. This is perhaps why standards of vehicle design and preslaughter handling tend to be better in countries such as Denmark and Sweden than other countries. In Australia and USA the marketing system is such that it provides no economic incentive to reduce losses (Grandin, 1989a). Transport is mainly by independent hauliers whose job is to transport animals from the producer to the abattoir as quickly and cheaply as possible. They receive no premium for good transport and are even covered by insurance for losses during transport. Vehicle design is only regulated in the interests of road safety rather than animal welfare. Abattoirs are often entirely independent of both hauliers and producers, and must buy animals where they can get them. A high percentage of cattle and pigs are also sold on a liveweight basis where the animals are paid for prior to slaughter. Losses due to deaths, bruises, DFD, PSE are absorbed by the slaughter plant.

A survey by Grandin in 1981 indicated that bruises on cattle were greatly reduced when producers changed to a carcass based system where bruise damage was deducted from their payments. Grandin (1993) later mentions that at one stage 40% of American pork was rejected by the Japanese market due to PSE, and this created a strong economic incentive to improve quality via better preslaughter handling. Improvements in the handling and transport of pigs then reduced PSE incidence and lead to 10% more pork being sold to Japan. In Australia there are many Japanese owned beef feedlots or feedlots that produce beef specific for Asian export, and there is high incentive for product quality from farm to slaughter in such highly valued market. These feedlots have better handling and transport facilities than domestic feedlots, and livestock personnel are educated in understanding the consequences of poor handling procedures on meat quality (Coleman, 1999).

In Denmark pig production is an important part of the economy, as 80% of pig production is exported to highly competitive markets (Barton Gade, 1993). In order to retain market share, Denmark has concentrated in product quality. This has initiated a close collaboration between the Danish Meat Research Institute, which is owned and financed by the industry, which ensures that the latest developments in animal handling and meat science are available to the whole industry and at a practical level.

Truck design

Design of livestock transport vehicles in different countries varies according to what is practical for each country. For example, vehicles in Australia are designed to have a much larger carrying capacity than those of the EU because greater numbers of stock are transported. The walls on many Australian trucks are open slatted, and some do not even have roofs on them. Strangely enough, even though Australia has much warmer weather conditions than in Europe, no trucks are ever equipped with fan controlled ventilation, as is the case in some Scandinavian trucks. An investigation of animal transport conditions in the EU found that the general design of animal transport vehicles were relatively constant within any one country, but varied between countries influenced mainly by climate (Christensen et al. 1994). In most European countries vehicles are designed with natural ventilation systems, with ventilation openings larger in warmer countries. In some three- deck vehicles, found mainly in Belgium, Italy and Holland, there is no system to adjust deck (tier) heights and it becomes awkward for handlers to get pigs to move out of the truck without stressing them. In UK, Denmark, and Sweden, trucks are built with a movable 2nd deck that can be raised slightly so that a person can get in to the truck to off load the animals, helping to reduce stress to pigs at unloading (Christensen et al. 1994).

Photo 1, App.2. shows the inside of a typical Danish animal transport vehicle. Note the smooth interior walls to reduce injury to the animals. Denmark has adopted a system for standardising animal transport to ensure quality control, and this is part of a plan called the 13- point plan. This has resulted in the improvement of transport vehicle design and has lead to consistent standards of transport across the country (Barton Gade, 1993). Most Danish transport vehicles are single decked and are used for both pigs and cattle. There are an increasing number of double decked (2 tiered) vehicles specific for pig transport. Three deck vehicles for pig transport are not allowed in Denmark due to legal requirements setting minimum heights for slaughter pigs at 1.10m. Vehicles are divided into 3 or 4 compartments to hold 15-20 slaughter weight pigs. The vehicles are made of aluminium alloy or sometimes plywood with either non-slip profiled aluminium or rubber flooring. Sawdust is mainly used as a bedding material during transport. All vehicles have roofing, either tarpaulin or insulated roof. All vehicles irrespective of number of tiers are equipped with a hydraulic tailgate lift which has rubber flooring. In single decked vehicles ventilation is natural. In two tiered vehicles 20-25% of the side walls have ventilation openings and mechanical ventilators at the front on each level, which is regulation in Denmark (Barton Gade et al. 1994). Approximately 15% of Danish trucks are equipped with showering systems in the truck for cooling pigs during hot weather (Barton Gade, Pers.Comm).

Swedish transport vehicles, similar to the Danish vehicles, are made to the same specifications across the country. Some lorries have trailers which can be connected to the front lorry so that animals can be loaded from the back of the vehicle and moved through the trailer to load into the front lorry section. Most vehicles are multi-purpose lorries for transporting cattle, sheep and pigs and can be single or double decked, the double decked vehicles being for pigs only. Livestock are generally transported in pens, unless they are used to being tethered, and in that instance they are usually transported tied by a halter. Bulls are often transported in separate pens if they have been raised this way. Otherwise, cattle trucks can generally take 4 cows per pen, with a total capacity of 16 cows in the whole truck. Pigs are most often transported in groups of 20 per pen. Transport vehicles are naturally ventilated, and truck carriages are often 25m^2 in size. All pig transport trucks are equipped with hydraulic tail- gates and have roofing (Grahn, 1998).

In the UK livestock are transported by specialist hauliers, farmers, or by trucks run by the abattoirs. Most livestock hauliers are small-scale operators, having fewer than 10 vehicles and most with only one vehicle. Many pig transport trucks are 2 decked, although 3 decked vehicles are becoming more popular. Vehicle types vary from lorries to semi-trailers. Small farm trailers are used by the farmer for shorter trips e.g. farm to sale yards. Larger trucks are divided into compartments with an average of 20 pigs in each compartment. Most trucks are made of aluminium alloy, although there are wooden sided vehicles in use. Flooring is predominately aluminium checker plate. Bedding in the form of straw is used when the vehicle does not have weld mesh. Newer vehicles have air suspension, and older vehicles spring suspension. Tiers can be both fixed and mobile. If fixed, then off loading of the upper deck is carried out using a steep internal ramp. No trucks were found to use an outer form of lifting device or adjustable loading ramp. Ventilation is natural corresponding to 10-15% of the wall area in older trucks and 30% in newer trucks (Barton Gade et al. 1994).

Information regarding commercial pig transport conditions in Spain can be found in Gispert et al. (in press). In this survey, all pig transport vehicles were lorries with natural ventilation, and hydraulic tailgate ramps for loading and unloading.

In Australia there is a great range of construction types for commercial livestock transport vehicles. Specialist hauliers run most transport trucks independent of abattoirs. The maximum size each trailer can be for semi-trailers is 12.5meters long and 4.6 meters high (Vic Roads, 1996). There are however, larger specifications for B-doubles or road trains but these vehicles are limited to transport on specified roads, and these roads are used for these vehicles only. Typical livestock trucks are semi-trailers with aluminium stock crates, that can be converted to single or double deck for cattle transport or triple deck for sheep, pig or calf transport (Herbert, 2000) (Photo 2, App.2). There are no trucks designed with hydraulic tail-gate ramps. However, in some abattoirs, sale yards or feedlots external loading ramps can be efficiently raised or lowered by a pulley system for muti-decked vehicles. Otherwise, trucks can be fitted with internal loading ramps, adjustable by a chain pulley system. The problems associated with this design are that they are very noisy, the ramp is very steep and many animals slip and fall in their incline up to the top deck of the truck, and it is also inconvenient and slow to use for the transport operator. There is also a gap left between the loading ramp and truck, which causes many animals to balk. Vehicles commonly have floor surfaces of steel weld mesh. Most pig and sheep transport trucks in Australia require animals to negotiate ramp inclinations at loading. Each deck can carry about 80-100 market weight pigs (70 kg), with 20-35 pigs per compartment, i.e. 4 pens each deck. Trucks are built with ventilation holes in the side walls (photo 3.App.2.) or are uncovered on the top deck (photo 4. App.2.), and never with automated ventilation, fans or sprinkler systems. Animals can easily be overheated in the hot Australian conditions, especially from the heat radiated off the metal walls of the truck. On each deck of a semi-trailer approximately 140 calves weighing 25-30 kg can be stocked on each deck as standard industry practice (Lewington, 1996).

In Australia there are no legal requirements for the design and construction of livestock transport vehicles other than those set down by the road safety authorities. There is however a code of practice that recommends basic standards.

Legislation

Industry recommendations and regulations for livestock transport vary considerably in different countries (Table 22). For example, in Australia, although large numbers of animals are transported over large distances, much greater than in Europe, there are no laws to control the standards of live animal transport. In the USA, the only federal legislation that is relevant to animal transport, is The Twenty-Eight Hour Law. It basically states that animals must not be confined to transport vehicles for more than 28 consecutive hours without feed, water and rest. In the EU in the last few years there has been extensive development of animal transport laws aiming to safeguard animal welfare and standardise transport conditions between EU member countries.

Table 22
Main differences in legislation/recommendations for transporting different classes of livestock in different countries

	EU	SWEDEN	AUSTRALIA
Max journey length (hrs) - adult ruminants - calves - pigs	 8 8 8	 8 (H_2O every 6hrs if temp >20^{o}c) 8 (H_2O every 6 hrs) 8 (H_2O every 3hrs if temp >20^{o}c)	 36 (can be ext to 48) 10 24
Min age before calves can be transported	4 days when navel is healed	2 weeks and must weigh over 50kg	4 days and must weigh 23kg
Latest pregnancy status for cows	48 hours before birth	3 weeks	4 weeks
Milking interval for lactating dairy cows (hrs)	12	12	24
Requirement for driver education in animal handling skills	Yes	Yes	No
Legislation on design requirements for trucks relevant to animal welfare	Yes	Yes	No

The European Union is presently made up of 15 member countries (states) including Denmark, Sweden, UK and Spain. The EU has the objective of a single market without border controls or comparable restrictions between member states. When regulations are developed, the Council of Europe holds conventions somewhat like an international workshop, where relevant published scientific evidence and practical experience of the different European countries are brought together. Once they are approved or ratified, it is the responsibility of the individual member states to incorporate the directives into national legislation. In July 1999 new regulations came into force to provide additional welfare protection for cattle, sheep, goats and pigs transported by road on journeys of greater than 8 hours. Provisions under Directive 91/628/EEC have been expanded to cover aspects of bedding, feed, access, ventilation, and water and feed supply. The regulations have a built-in review system: by October 3rd 2003, the Commission is required to submit a report to the Council on the implementation of the legislation. The comprehensive laws set down the minimum standards for animal transport aiming to harmonise journey times, resting periods, feeding and watering intervals, space allowances and general transport conditions in member states.

In the drafting of the animal transport directives (Official Journals L 340, L148, L174, 91/628/EEC, 90/425/EEC, 91/496/EEC, 95/29/EEC,95/29/EEC) there have been many disagreements between countries to set uniform standards. According to Schmidt´s 1995 report reviewing animal welfare legislation in the EU, there is an obvious north/south divide, with northern countries having more legislation protecting farm animal welfare than the southern countries. Also the southern countries such as Spain, Portugal and Greece have complained that new regulations governing animal transport are uneconomic (Vet Record, 1995). EU regulations are directly applied without the need for national measures to implement them. The directives however, bind Member countries as to the objectives to be achieved while leaving the national authorities the power to choose the form and the means to be used. This is causing widespread debate between member states, as some countries for example UK, have developed the directives into national legislation, but countries like Spain have not.

The area which has proven to cause the most contention between member states, is the issue of maximum allowable transport duration for different classes of livestock. Road transport vehicles are now classified into 2 categories i.e. 'Basic' and 'Higher Class'. 'Higher Class' vehicles have certain design requirements, which if fulfilled permits animals to be transported on longer journeys (see Table 23).

These vehicles must:

- carry appropriate feed for the animal species transported and for the journey time;
- be equipped so that there is direct access to the animals at all times;
- have moveable panels for creating separate compartments;
- be equipped for connection to a water supply during stops, and the water device fixed or movable to provide water for the animals onboard;
- in the case of vehicles for transporting pigs, sufficient water must be carried for watering during the journey.

Ventilation requirements for 'Higher Class' vehicles are more detailed and further state that;

The ventilation system must be designed in such a way that:

- it can be used at any time when the animals are in the vehicle whether it is stationary or moving,
- it ensures the efficient circulation of unpolluted air.

To that end, operators must provide:

- either a forced ventilation system, the details of which are to be determined after consultation of the Scientific Veterinary Committee in accordance with the procedure laid down in Article 17 of Directive 91/628/EEC,
- or a ventilation system which ensures that a range of temperatures from 5 °C to 30 °C can be maintained within the vehicle for all animals, with a + 5 °C tolerance depending on the outside temperature. This system must also be equipped with an appropriate monitoring device.

Vehicles that do not conform to the above standards are considered as 'Basic Vehicles'. Animals transported on these vehicles are restricted to much shorter journey lengths, i.e. 8 hours for all livestock.

Table 23
Maximum journey lengths allowable for livestock on 'Basic' and 'Higher Class' vehicles

Livestock Type	**Maximum Journey length before rest period**
'BASIC VEHICLES'	
All Livestock	8 hours followed by 24 hours rest
'HIGHER STANDARD VEHICLES'	
Unweaned piglets, calves, lambs, kids, and foals still on a milk diet	9 hours followed by a mid-journey rest of at least one hour, then a further maximum of 9 hours i.e. total journey time = 19 hrs
Other cattle, sheep and goats	14 hours followed by a mid-journey rest of at least one hour, then a further maximum of 14 hours i.e. total journey time = 29 hrs
Pigs	24 hours with liquid and, if necessary, food every 8 hours
Horses (excluding registered horses)	24 hours with liquid and, if necessary, food every 8 hours

(WATO Guidance, 1998).

When a journey time exceeds the maximum permitted in the above table, the animals must be unloaded and rested for 24 hours at a staging point where food and liquid will be provided before the journey may continue. Council Regulation 1255/97 lays down the criteria for staging points. Mid journey rest may be given on or off the vehicle and must be for at least 1 hour.

A journey is considered to begin from the place where the animal is first loaded on to a means of transport, or any place where the animals have been unloaded and accommodated for at least 10 hours.

The final destination is considered to be the place at which an animal is finally unloaded from a means of transport, but excluding a staging point or a transfer point.

Animals on journeys exceeding 24 hours from the place of departure and taking account of the place of destination, must have an itinerary - including any staging and transfer points - whereby it can be ensured that the animals are rested, fed and watered and, if necessary, unloaded and given accommodation in accordance with the requirements of the Directive for the type of animal to be transported.

Legislation for staging points include the following:

- that animals are protected from extremes of weather, while allowing adequate ventilation;
- animals should be handled with care and with minimal use of goads, and they should be kept in the same groups as they have been transported with;
- the facilities should be adequately disinfected, and all staff should wear protective clothing that can be sterilised;
- bedding for animals must be changed in the pens and pens disinfected after each consignment of animals;
- the staging post will have to be kept free of animals for at least 24-hours every 7 days before the arrival of new animals;
- a requirement to provide facilities for separate accommodation for animals that are diseased, injured or in need of individual attention;
- all necessary veterinary treatment is to be provided at the cost of the transporter,
- each staging post shall be under the supervision of an official veterinarian.

In May 1999 further EU legislation came into force requiring that all animals destined to export markets must be inspected by an official veterinarian to ensure that animals are not transported that are sick, diseased or unsuitable for welfare reasons.

The EU Directive states that; "Member States shall ensure that the person in charge of the animal transport undertaking; entrusts the transport to staff who possesses the necessary knowledge to administer any appropriate care to the animals transported." EU inspectors may carry out on-the-spot checks in collaboration with the competent authorities of the Member States. Member States shall take the appropriate specific measures to penalise any infringement of the Directive. In the event of repeated infringements, or of an infringement resulting in severe suffering to animals, a Member State may take the measures necessary to correct the shortcomings noted.

In the UK animal transport to and from markets, to slaughter, and, particularly, on export journeys, is a matter of widespread public concern. The Government recognises this concern and has afforded a high priority to ensuring that the welfare of animals is protected during transport. This is achieved through national regulations and enforcement, as well as through supervision and guidance. Legislation is by the Welfare of Animals (Transport) Order 1997 ("WATO"). As well as providing for EU-wide maximum journey times, feeding and watering intervals, and proper rest periods for animals to recover from journeys, the rules give strengthened enforcement powers through, for example, authorisation of transporters and route plan requirements. This is supported by comprehensive codes of practice, and there are regular checks and inspections of animal transport vehicles by local authorities. The State Veterinary Service (SVS) carries out inspections on farms to check that the legislation and the welfare codes are being followed. In addition to spot checks and planned visits, the SVS follows up all complaints and allegations of poor welfare on specific farms or in transport as a matter of urgency. Where welfare problems are found, advice or warnings to farmers and transporters, in most cases, results in satisfactory improvements being made - follow up visits are made to check on this. However, where justified, prosecution action is initiated, often in co-operation with local authorities and/or the RSPCA (MAFF, 2000).

The UK MAFF has developed a sophisticated data- base that records animal transporters details and any infringements logged against the transporter. A livestock transport may have their licence revoked or conditions imposed on them if:

- They have 3 infringement notices against them.
- They have failed to return 3 route plans.
- They have deviated from 3 route plans without adequate explanation
- Have one infringement involving serious suffering.
- One conviction for an animal welfare offence.

MAFF have produced a detailed guide on the assessment of practical experience for livestock handlers and transport drivers in the handling, transport and care of animals. Whenever vertebrate animals are transported on journeys of over 50km but less than 8 hours by road (i.e., under a General Authorisation), the transporter must ensure that they are accompanied by an attendant who has the appropriate knowledge and ability to look after them during the journey. But, if animals are transported on journeys over 8 hours by any journey by sea, rail or air (i.e., under a

Specific Authorisation), the attendants accompanying the animals must have demonstrated their competence, either by obtaining a qualification approved by the MAFF or through an assessment of practical experience. Evidence of assessment has to be provided in the form of a certificate signed by the employer or an independent assessor.

Denmark implemented the EC directive on animal transport into national legislation in 1993. In addition, the Danish pig industry has guidelines for the transport of pigs via the agreement signed by the Federation of Danish Pig Producers and Slaughterhouses and the Danish Hauliers Association which was set in December 1988, and have been incorporated into the contracts which abattoirs have with independent hauliers.

The legislation for the transport of animals in Denmark basically sets down the regulations to that of the EU. However, the Danish meat industry put research gained from the Danish Meat Research Institute into practice, and developed the so-called 13 point program. This program which has been readily adopted by the livestock industries provides guidelines for producers, hauliers and abattoir personnel to ensure the following:

- Considerate treatment of animals.
- Good uniform meat quality.
- Low transport mortality.
- A delivery ensuring protection of a herd's health.
- Rational collection and transport.

The stocking densities in Denmark are different to EU legislation in that they are increased in the event of journeys over 4 hours. For example the stocking rate allowed on national transport vehicles not travelling more than 4 hours for 100kg pigs is $0.35m^2$. For journeys over 4 hours the stocking rate should be $0.42m^2$ per 100 kg pigs with an increase of up to 20% in warmer weather and on longer transport durations (Barton Gade, 1993).

All drivers of commercial livestock transport vehicles in Denmark must be experienced and trained in the handling of livestock. It is part of the registration requirements for livestock hauliers. There is also a 2 day compulsory course for drivers run by the Danish hauliers association in consultation with the Danish Meat Research Institute (Barton Gade, Pers.Comm).

The Act on the protection of Animals in Denmark specifies that district veterinarians, employees of the Veterinary Service, and private veterinarians carry out enforcement. Enforcement is done in co-operation with the police. A veterinarian who becomes aware than an animal is being treated cruelly shall inform the police. The police have powers to order the responsible person to seek veterinary treatment or order that the animal be destroyed if it is suffering. Owners or persons employed in transportation, or other tasks in connection with the treatment of animals, shall give inspection authorities appropriate assistance in connection with the performance of the control under sections of the Danish Protections of Animals Act. Any person found guilty of an offence under the Danish Animal Protection Act is punishable by fine, simple detention or imprisonment for up to 1 year.

In February 1995 the Permanent Animal Welfare Advisory Group to the Swedish Board of Agriculture was informed that the Transport Directive (91/628/EEC) was to be implemented in Sweden. The Advisory Group found that the Directive legislation on transport was not adequate in two main respects; transport time before animals are allowed to get water and feed, and transport of young animals or animals in late pregnancy. In Sweden the latest pregnancy status that animals are allowed to be transported is not more than 3 weeks before giving birth or 3 weeks after giving birth, and if the transport is more than 24 hours, 6 weeks. The EU directive states 48 hours, and has no specification for longer transport times, or for animals after birth. In Australia, cattle which are more than 8 months pregnant are not recommended to be transported, and cattle that have recently given birth should not be transported until after 4 days. Swedish animal transport legislation stipulates that pigs, lambs and goats must be at least 2 weeks old before transport is allowed, and calves at least 2 weeks old and over 50kg. The EU legislation states that infant animals in which the navel has not completely healed are considered as unfit for transport i.e. animals must be at least 4 days old, this is the same as the Australian recommendations for calf transport. In Swedish legislation pigs younger than 3 months, and cattle 6 months, must be given water each 6th hour. At temperatures above 20^{o}C all pigs must be given water after each 3rd hour and adult cattle every 6 hours (Swedish Animal Protection Act, 1988; SJVFS1996:105, SJVFS1997:82).

Livestock transporters in Sweden must undergo a certified training course in animal handling and transport run by the commercial transport companies every year before they can commercially transport livestock. Drivers then must undertake refresher courses annually.

Swedish animal transport legislation requires that during transport, animals must be inspected at least every 2 hours. These inspections shall be notified in a journal, noting the time if the inspection and signed by the inspector. This is not required under EU legislation.

Swedish transport companies are audited for compliance with regulations and abattoir veterinarians inspect animals as they are unloaded for welfare and disease concerns. The Swedish government appoints animal inspectors for each municipality, who have the authority to inspect transport vehicles and farms for breaches of animal welfare.

The Swedish government initiated an investigation into commercial animal transport conditions in order to assess compliance with regulations, industry standards and identify problem areas. Inspections of trucks and a questionnaire survey on the drivers were conducted in 1999 on randomly chosen transport vehicles through the whole of Sweden. The questions were designed to investigate average journey lengths, stocking rates, ventilation types, classes of animals transported, numbers of injured animals or deaths, route plans and any problems encountered in the transport of animals from farm to slaughter (Dahlén, 2000). The results are still being analysed, but will provide an excellent perspective of general animal transport conditions in Sweden.

Although in Australia there is no actual national legislation for animal transport, there are the "Australian Model Codes of Practice for the transport of Animals", which have been prepared for the Standing Committee on Agriculture and Resource Management (SCARM) by representatives of state and Federal Departments. These codes provide recommendations for transporting livestock under different situations and are generally adopted by the industry.

There is no provision in Australia for transport vehicle inspections for animal welfare reasons. However, under state anti-cruelty laws, if animals are found to be suffering due to ill treatment, the persons responsible can be liable. In Victoria, Codes of Practice are given status under the Prevention of Cruelty to Animals Act (1986), and husbandry conducted outside of the Code of Practice could lead to a possible offence under the act. In Victoria, livestock inspectors are employed to safe guard the health and welfare of farm animals. They have authority to interview and prosecute offenders for acts of animal cruelty.

In practice, it is very difficult to prove in a court of law that animals have been cruelly treated during transport, and there is also difficulty in pin pointing who is the responsible person in the chain of events from farm to slaughter. Livestock vehicles are rarely checked for animal welfare problems by livestock inspectors or police. However, livestock must be inspected at the abattoirs by a veterinarian, who is responsible for reporting to authorities, obvious cases of animal cruelty. There is no requirement for people handling and transporting livestock in Australia, to be certified or experienced in that area. There are no official training programs available for livestock handlers (Wythes, 1994). However, the National Code of Practice for handling and transport of animals do state that stock handlers should be properly instructed and knowledgeable about animal welfare and be skilled in handling animals under varying climatic conditions.

There are many welfare concerns with the transport of casualty animals or those regarded as 'unfit' for transport. There needs to be greater definition in legislation that identifies at what stage animals should be considered 'unfit' for transport, and/or a casualty animal. Under the Australian Code of Practice for the transport of cattle, the only reference to 'fitness to travel', is a sentence stating that only animals fit to travel should be selected for transport. There are no explanations as to what is considered an animal 'unfit for transport'. EU legislation simply states 'no animal shall be transported unless fit for the intended journey. Animals that are ill or injured shall not be considered fit for transport'. The UK legislation is a little more detailed and the WATO guidance (1997) gives a description of how to decide if a casualty animal can be sent to an abattoir. For example, questions to consider if transport is suitable include:

- can the animal be loaded without using force and additional suffering?
- can the animal comfortably bear weight on all four legs and if it is likely to stand during the journey, can it do so without pain or distress?
- what is the duration of the journey?
- what is the nature of the road over which the animal will be transported?
- is the animal's condition going to deteriorate significantly over the time it takes to reach the abattoir or treatment centre?

An example where these questions become relevant is for dairy cows at the end of their productive life. These animals can be weak and emaciated or suffering from cancers, mastitis or have stretched udder ligaments. Legislation and recommendations should be designed so that there is a method of deciding whether these types of animals are fit for transport, or whether they should be put down at the farm.

In countries such as Scandinavia and the UK, there is greater awareness and concern of how animals in farming are being treated than in countries such as Spain. This is reflected by the level of regulation of farming practices in northern European countries compared to southern countries. These cultural differences as well as politics will continue to cause problems between EU member states when agreeing upon uniform animal transport laws. This exemplifies the importance of conducting further research in animal transport and welfare, which is relevant to industry needs. There is also an urgent need for government authorities to adopt controls to check compliance of animal transport legislation and ensure certain standards are kept. Legislation is useless if there is no system in place to enforce it.

FUTURE DEVELOPMENTS

Fortunately scientific research is continually developing and discovering ways of improving preslaughter handling and transport conditions for farm animals. Consumers are becoming more aware and concerned about the treatment of farm animals. This is in part thanks to the improved information technology causing a greater exposure of media coverage on the subject. Greater consumer awareness has caused a market niche for animal welfare friendly products. The UK, Sweden and Denmark are good examples of where this is happening. In supermarkets people are able to choose meat, milk and eggs from farms that are under an auditing program for animal welfare. In the UK for example, the initiative called Freedom Foods has been developed. If producers follow a set of conditions based on good animal welfare under guidelines set by the RSPCA, then they are able to sell their products as labelled animal friendly (Schmidt, 1995). Each farm, transport operator and abattoir is subject to annual inspection and random checks to establish whether they are complying with the standards. Market research has shown that people who are prepared to pay extra for welfare friendly products will on average pay up to 14% more (Gregory, 1995), and in October 1994, Freedom Food pork cutlets were retailing at 8% more than standard pork cutlets.

The animal welfare concerns of the EU may well in the future cause trade barriers to countries that do not have good animal welfare standards. For example, the EU could impose animal welfare standards in Australia as it has with abattoir hygiene. Australian abattoirs that slaughter animals destined for EU markets are audited by authorities for specific standards of hygiene and chemical residues set by the EU which are above the requirements demanded in Australian domestic abattoirs. EU authorities could just as easily demand that there are certain standards of animal welfare that are required in order for the meat to be accepted for export. For example, many animal transport vehicles and conditions in Australia would be found to be unsuitable under the latest EU transport directives, especially in the area of ventilation, stocking rates and maximum journey lengths. Approximately 45% of Australia's beef and 49% of its lamb goes to welfare sensitive markets, and 23% of beef and lamb is exported to the EU (Gregory, 1998), therefore it could be in Australia's interests to develop credible animal welfare standards.

In some countries mobile slaughter plants are being developed, eliminating completely the need for animals to be transported to slaughter. These mobile slaughter trucks drive to the farm where animals are slaughtered and processed inside the truck. In Sweden a complete mobile abattoir has been approved by the Swedish government authorities to slaughter and process deer and goats. It complies with EEC export processing requirements, and is operating as an experiment to test the viability of such a system. The truck has the capacity to process 60 animals per hour, and during an 8 hour shift can exceed 500 carcasses. In Poland and Russia, mobile slaughter trucks are also being developed. This is because the supporting infrastructure lacks an organised market and state, but the plentiful supply of meat on small farms makes the mobile slaughter plant ideal (Viere, 1994). If mobile slaughter houses are found to be viable, this system would be most advantageous from an animal welfare point of view.

Thanks to advancing technology, conditions for animal welfare during transport are continually improving. The development of cameras in transport vehicles so that livestock can be continually monitored is becoming more popular and is economically viable. The development of GPS systems has lead to improved route planning, with journeys being as direct as possible and on the best roads. Mobile communications has allowed vehicles to be in constant contact and trucks can take calls mid journey, which allows more farm pickups and less detouring. The advancement in vehicle designs such as installation of mechanical and thermo-regulated ventilation systems and hydraulic loading equipment is making the actual journey for animals more comfortable.

CONCLUSIONS

Scientific results from measuring behavioural and physiological responses of livestock to the transport process prove that transport is an inherently stressful procedure for them. Research also shows meat quality defects such as DFD, bruising and PSE can be caused by poor transport and preslaughter conditions. This is why the journey from farm to slaughter should be as short as possible. However, the increasing trend of industry centralisation means that the transport distances between farm to slaughter are likely to increase. Also, the international trade of live animals is of high economic viability, and under present trade laws it cannot be stopped (Gregory, 1995). Therefore there needs to be stringently enforced regulations applied in the livestock transport industry at all levels from farm to slaughter. These regulations and recommendations should be based on reference to biological reality, scientific research and the commercial pressures under which the livestock transport industry operates.

Studies to determine the amount of stress on farm animals during routine transport often have highly variable results and are difficult to interpret from an animal welfare standpoint. Much of the variability between handling studies is likely to be due to different levels of psychological stress. Fear responses in a particular situation are difficult to predict because they depend on how the animal perceives the handling or transport experience. The animal's reaction will be governed by a complex interaction of genetic factors and previous experiences.

Of all farm species, pigs generally present the greatest risk of sudden death as a consequence of transport stress. According to many researches (Guárdia et al.1996; Warriss, 1998) the main causes of preslaughter mortality include environmental factors (handling and weather) and the genotype. Warris and Brown (1994) reported a curvilinear relationship between pig mortality in transport and temperature. Above about 15 to 17° C the detrimental effects of high temperatures become far more serious (Warriss and Brown, 1994). The detrimental effects of warm weather conditions can be controlled if appropriate management is taken such as transporting animals in thermo-regulated trucks, or transporting stock in the cooler parts of the day or at night, or showering pigs in transport or lairage. The importance of effective ventilation in trucks was demonstrated in Denmark, when statistics showed that pig mortality was halved over one year as a result of mechanical ventilation being installed in the abattoirs transport vehicles (Barton Gade et al. 1996). Feeding pigs on the day of transport predisposes them to travel sickness and increased risk of death (Guárdia et al. 1996). Research indicates fasting pigs before transport of between 12 and 18 hours pre-slaughter is optimal for pig welfare and meat quality.

Although mortality rates in sheep and cattle transport are reportedly low, there are instances in the export trade where mortality rates are excessive. Poor ventilation during transport and change in feed seem to be the main reasons for deaths on voyage for ruminants. Age of calves seems to be the greatest factor effecting calf mortality during transport. Younger calves are more susceptible to the effects of dehydration and disease.

The pH limit for normal, DFD and PSE meat varies from country to country, animal species, and further from different meat processing companies. It also varies depending on how it has been determined e.g. by a microbiologist, by a meat inspector in an abattoir, or by a trade organisation, and also from what muscles the pH levels are measured. These variations can sometimes lead to misinterpretation of DFD or PSE incidence. In countries where pigs are selected for higher lean meat content, PSE problems are greater, due to the correlation between lean meat content and stress susceptibility. In countries such as Denmark and Sweden, pigs have been selected against stress sensitivity, and this has resulted in much lower incidences of PSE compared to other countries such as Belgium and Germany. The handling technique of keeping pigs in small groups in transport and preslaughter in countries such as Sweden and Denmark has also helped to reduce PSE incidences. Shorter lairage times slaughtering after 2-3 hours and not mixing pigs after arriving at the abattoir has also helped reduce DFD rates in Scandinavian pigs. However, lairage times should be set in accordance with transport duration. After long transport six hours of lairage allowed liveweight to recover to pre transport levels according to Brown et al. (1999). Mixing of unfamiliar cohorts seems to be the main contributing factor causing DFD in Europe in all livestock species. In Scandinavia castration is not usual, therefore the mixing of bulls or boars pre slaughter can escalate DFD incidence. However, in Australia it seems that rough preslaughter handling and long transport durations are the greatest factors causing DFD meat.

Weather conditions, size, species and weight of livestock, animal temperament, journey duration, standard of truck driving, road conditions and type of transport facility are all factors that make it difficult to make rigid loading density recommendations for the transport of livestock. Although there is conflicting research on optimum stocking densities, there seems to be a consensus that stocking density should be such that allows animals to get back up again if they fall over, and rates should be lower in warmer weather especially in the event of no climate control. On shorter journeys, it can also be more practical to have higher stocking rates. It has been shown through the studies of Barton Gade and Christensen (1998), that higher stocking rates for pigs ($0.35m^2$) are practical on shorter journeys. However on longer journeys (over 8 hours), the stocking rates should be lower ($0.42m^2$) in order to allow pigs to lie down and rest (Lambooij et al. 1985).

Generally livestock sold through a live auction system are more bruised and exhausted than those sent direct to abattoirs. This is due to the greater amount of stress and handling involved with live auctions. Horned cattle transported to slaughter are also more prone to bruising and lowered meat quality than polled cattle. Tipping of horns in Australia is an established practice in slaughter cattle production. It has been shown however, that this practice is ineffective in reducing bruising rates. Despite this information, it has been estimated that in Australia approximately 36% of cattle are horned (Wythes, 1979). De-horning of young animals or better still, the breeding of polled animals is recommended to reduce potential bruising rates.

The movement of livestock on and off trucks can be enhanced with equipment designed to minimise fear provocation in livestock and better fit their sensory preferences. Design features such as circular yards, curved lane ways, races with solid or semi solid fences and long tapering entrances, should exploit the vision, circling and follow the leader habits of cattle and sheep. Dead ends, sharp corners, and obvious lighting contrasts should be avoided. Scandinavian research has shown that moving pigs in groups of 15-20 optimises welfare and meat quality as there is less tendency for pigs to fight in small groups. Since loading and unloading contribute a lot of stress in animal handling, it is very important to have adequately designed facilities. In Denmark and Sweden, most pig transport trucks are fitted with hydraulic tailgates, which are the most ideal loading facility for pigs. Loading ramps with a level landing apron at truck height, or a slope of less than 20^o aids smoother movement of livestock on and off trucks.

Stock handlers working in the transport or abattoir industry deal with large numbers of livestock every day. The repetitiveness of handling large numbers of stock, and being under pressure to move these animals to keep up with contracts and abattoir slaughter lines, can have the effect of desensitising animal handlers to the welfare needs of the animals they are handling. Regular education of stock handlers in the area of animal behaviour and the consequence of poor handling could help prevent this situation occurring. Some handlers, although working all their life with livestock, may not actually know that livestock have poor close range vision, can confuse obstacles and shadows as actual physical barriers, and are more stressed by noise and electric prodder use. Unless the people in charge of livestock, possess and use, the appropriate handling skills then industry cannot utilise the advantages of properly designed livestock yards and transporters, or of well researched and implemented management practices. Poor handling generally overrides well designed facilities, consequently impairing product quantity and quality. Producers need to develop an understanding of the market demands, rather than just concentrating on weight of animal at sale. They need to implement on-farm preparation practices. For example, ensuring animals are drafted quietly and are ready for loading when the transporter arrives, and that livestock arrive at the abattoir in adequate time to rest before slaughter. Adhering to pretransport fasting recommendations is also important not only for reasons of better hygiene, but in the case of pigs, if fed on the day of transport, they are predisposed to travel sickness. The importance of educational extension material, aimed at the people working at the ground level in the industry is of utmost importance if standards of animal welfare and handling are to be improved.

Scientific results from measuring behavioural and physiological responses of livestock to the transport process prove that transport is an inherently stressful procedure for them, and under poor conditions meat quality defects are increased. Where conditions in transport are good, long (between 15 and 24 hours) transport durations for livestock to a certain extent, can be no more stressful for livestock than short journeys (Wythes, 1994). If transport conditions are poor for livestock, even the shortest journeys can be highly stressful and result in high meat quality losses. It is difficult to define an exact limit for the period which ruminants can safely be deprived of food and water during transport. It will necessarily be a subjective assessment because the biochemical changes and liveweight loss changes tend to be linear with time, with no obvious break points. However, most research indicates that transport should be kept under 24 hours for adult livestock. The question whether animals should be lairaged mid transport for rest periods and for how long, and under what conditions is problematic. Full recovery from periods of transport has been shown to take various lengths of time. Most research indicates that a lairage stop of only a few hours is detrimental rather than beneficial to animals. Livestock cannot eat sufficient amounts of food in such a short period of time to satisfy their needs. What they do consume can lead to an increased water deficit because their drinking pattern means that they will not have enough time to drink sufficient water with the type of drystuff usually offered. Feeding and watering livestock in a commercial situation is also a problem in terms of practicality. This is because it is necessary for all animals to have simultaneous access to food and water to prevent the stronger animals from excluding the weaker. Within a lairage the feeding and watering space should therefore not be limiting. Animal temperament is another important issue to consider. For animals not used to being handled, unloading mid way for a rest period may actually cause more stress on the animals than allowing them to continue and get the journey over with. However, if the weather conditions are hot, and the transport vehicle has no adequate ventilation, or the vehicle is overstocked, or travelling on rough roads, mid journey resting periods may well save the lives of many animals.

Long transport periods for livestock with out rest periods should only ever be permitted under the following conditions:

- all livestock are in good, healthy condition and are old enough to cope with transport stress;
- the transport vehicle is in good repair with good suspension and has good ventilation characteristics;
- the stocking rates are such that all animals can lie down and get up;
- all livestock are able to be inspected on a regular basis;
- the truck is driven with care;
- the route of travel is along smooth roads.

It is important to note that research conducted on the effect of transport duration on animals is generally under good transport conditions. Therefore results do not necessarily reflect industry practice. In situations where transport conditions are poor, these results become irrelevant.

Conditions under which Australian livestock are produced are very different to that of Europe. The sheer numbers of livestock transported, and the environment in which they are produced directly influences the manner in which livestock are transported. These differences must be recognised. For example unloading cattle that came from the Australian outback every 8 or 14 hours (as stipulated in EU legislation) for a rest period on long journeys would not be in the interests of those animals, because of the stress related to handling animals not used to being handled. The species must also be considered when deciding the right conditions for transport of livestock. For example, cattle generally have more difficulty than pigs or sheep to keep balance on journeys because of their size and weight. This has bearing on how many dividing walls should be used to help support cattle inside the truck. Pigs generally require more area in transport than sheep as they require a space and substrate in order to lie down, while sheep spend most of their time standing on a journey. Young calves lie down much more than adult cattle during transport, and therefore it is very important to ensure the stocking density for these animals allows that. In general there needs to be more research conducted on the behaviour of animals while in transport and during rest periods so that adequate rest and feed and hydration intervals can be more adequately set in accordance with animal welfare.

The search continues for practical ways for the industry to improve welfare standards and adopt strategies to maximise carcass weight and meat quality. To ensure that strategies are in harmony, any assessment must take a broad approach and consider all sources of product loss. For scientific research in animal transport to be of any use to the industry it must be in relevance to industry practices. Other effective methods for improving standards of livestock preslaughter handling and transport in the industry include financial incentives for good animal handling practices and financial penalties for bad animal handling practices. Education material for farmers and transport operators on recommendations for transporting farm animals should be readily available and easy to understand. When investigating what the different animal transport requirements and regulations were for different countries in relevance to this report, the accessibly of information varied considerably. The UK proved to be the easiest in gaining information. The guidance on the animal transport laws produced by MAFF provided comprehensive information to the requirements for animal transporters. This was supported by easy to read pamphlets. Australia provided comprehensive codes of practice, and also various pamphlets on the transport of calves. In Sweden, no such guidelines could be found. Sweden was the most difficult country to find out what the requirements and legislation relevant to animal transport were. After many calls to the Agriculture Department, finally the legislation was sent, in its exact form. From a farmer's point of view, the legislation is difficult to read and follow. The importance of extension material to help communicate scientific research, regulations and recommendations to farmers, transporters and people working in the livestock industry is of utmost importance if standards in animal transport and preslaughter handling are to be improved.

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APPENDIX 1.

Country	Land area (sq kms)
USA	9 666 861
Australia	7 682 300
Denmark	43 094
Sweden	449 964
UK	242 752
Spain	504 782

(Encarta Encyclopaedia, 2000)

	Livestock production (MT) 1998					
	Australia	**Denmark**	**Sweden**	**Spain**	**UK**	**USA**
Beef	2 008 979	163 000	143 000	670 000	678 000	12 050 000
Mutton and lamb	607 814	1 500	3 500	221 000	361 000	104 800
Poultry Meat	573 444	1 74 370	81 000	870 000	1 191 000	13 600 000
Pig meat	361 858	1 725 000	330 000	2 925 000	1 048 000	8 785 000

(FAO, 2000)

	Total Livestock Exports (MT) 1998					
	Australia	**Sweden**	**Denmark**	**Spain**	**UK**	**USA**
Beef	1 191 886	8193	126 992	125 379	9 456	909 463
Mutton and lamb	257 713	50	493	14 476	103 209	2 690
Pig meat	15 022	40 249	1 203 072	275 306	271 312	499 342
Poultry Meat	20 439	9 455	130 738	48 341	204 275	2 553 383

(FAO, 2000)

	Total Live Animal Exports (Head) 1998					
	Australia	**Sweden**	**Denmark**	**Spain**	**UK**	**USA**
Cattle	128 755	4 768	22 393	114 385	126	285 336
Sheep	5 117 443	0	7 940	319 684	310 763	665 104
Pigs	1 011	7 004	1 732 817	532 316	250 662	229 454

(FAO, 2000)

	Total Live Animal Imports (Head) 1998							
	Australia	**Sweden**	**Denmark**	**Spain**	**UK**	**USA**	**Holland**	**France**
Cattle	70	5	59	576 740	3 430	2 036 746	371 470	275 508
Sheep	0	0	0	392 109	81 324	46 119	295 991	686 390
Pigs	0	0	712	1 110 999	203 174	4 122 914	174 655	393 927

(FAO, 2000)

APPENDIX 2.

Photo 1: The interior of a Danish pig transport vehicle

Photo 2: Typical Australian double deck semi-trailer road cattle transport vehicle, used for sheep and pigs as well**.**

Photo 3: Australian enclosed transport vehicle with ventilation openings in the wall**.**

Photo 4: Open roofed Australian cattle transport vehicle.