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The welfare of livestock during road transport.

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Abstract

The welfare of animals during transport should be assessed using a range of behavioural, physiological and carcass quality measures. In addition, health is an important part of welfare so the extent of any disease, injury or mortality resulting from, or exacerbated by, transport should be measured. Many of the indicators are measures of stress in that they involve long-term adverse effects on the individual. Some of the key factors affecting the welfare of animals during handling and transport which are discussed are: attitudes to animals and the need for training of staff; methods of payment of staff; laws and retailers' codes; genetics especially selection for high productivity; rearing conditions and experience; the mixing of animals from different social groups; handling procedures; driving methods; stocking density; journey length; increased susceptibility to disease; and increased spread of disease. In order that welfare can be good during transport, it is important that all of those involved are properly informed about the animals and how to assess their welfare. There should be careful planning of journeys and suitable vehicles should be selected. Space allowances should be suffi cient for the animals to lie in most species, to stand in the case of all horses and cattle and sheep on short journeys, and to move to get food and water if the journey is long enough for this to be necessary. Vehicle design and space allowance should allow for adequate inspection of each animal on the vehicle or, if this is not possible, journey time should be kept short. Long journeys, the term long having different meanings for different species as explained below, should be avoided wherever possible and much better conditions are needed if journeys are long. Vehicles should be driven more carefully than vehicles with human passengers and sudden turns and braking should be avoided, especially on roads with sharp bends or at right angle turns into other roads. Ventilation management and other efforts to avoid harmful physical conditions are important. Transport should be managed so that disease susceptibility is not high and disease spread is minimized.

Introduction and Definitions

The handling, loading, transporting and unloading of animals can have very substantial effects on their welfare and meat quality. The welfare of an individual is its state as regards its attempts to cope with its environment (Broom, 1986). Hence, welfare is a measurable characteristic of an animal at a particular time or during a period. Animal protection is a human activity that should lead to better welfare. Coping means having control of mental and bodily stability and welfare includes both the extent of failure to cope and the ease or difficulty in coping. Welfare varies on a scale from very good to very poor. Health is an important part of welfare while feelings, such as pain, fear and various forms of pleasure, are components of the mechanisms for attempting to cope and so should be evaluated where possible in welfare assessment (Broom, 1998, 2001b, 2006a; and see Chapter 1, this volume). Where an individual is failing to cope with a problem, it is said to be stressed. Stress is an environmental effect on an individual, which overtaxes its control systems and reduces its fitness or appears likely to do so (Broom and Johnson, 2000). There are many different systems in the body whose function is to maintain the individual in conditions that it can tolerate. When one or more of these systems cannot correct for the environmental impact, they are said to be overtaxed, the individual starts to become stressed. Reduced fitness means that the individual is more likely to die or be unable to spread its genes in the population. Some of the effects of the environment may simply be stimulation or useful experience or a physiological response involving the adrenal gland, which has no adverse consequences, and the individual is not stressed. All stress involves poor welfare. However, there can be poor welfare without stress because the poor welfare has no long-term consequences, for example temporary pain or distress. Pain is an unpleasant feeling that is generally strongly avoided, so any pain, or indeed any other negative feeling, means that welfare is poor. These issues are discussed further in several papers in Broom (2001a).

In this report, after presentation of a summary of information about land transport, the factors, which can result in stress during transport, are introduced. The methodology for assessing the welfare of the animals during handling and transport is then explained. Finally, some of the various factors, which affect the likelihood of stress, are discussed with examples from work on cattle and sheep.

Information About the Amount of Land Transport

Of all species of animals transported for slaughter, by far the largest numbers are of chickens reared for meat production. With more than 48 billion chickens produced each year in the world and transport occurring at least twice, the total number of journeys in the world in 2005 was about 96 billion (FAOSTAT, 2006). [AU3] Comparable figures for other species are shown in Table 7.1.

A typical journey

The Federation of Veterinarians of Europe has stated (FVE Position Paper, 2001) that it has always been of the opinion that the fattening of animal should take place within or near the place of birth. Animals should be slaughtered as near the point of production as possible. The journey time for slaughter animals should never exceed the physiological needs of the animal for food, water or rest; the long-distance transport

Table 7.1. Numbers of farmed animals produced in the world in 2005, most of which would be transported to slaughter. (From FAOSTAT, 2006.)

Animal	Millions of animals
Chickens reared for meat production	48,000
Hens for egg production	5,600
Pigs	1,310
Rabbits	882
Turkeys	689
Sheep	540
Goats	339
Cattle for meat production	296
Cattle for milk production	239
Fish of many species are farmed but live transport often does not occur	

of animals for slaughter should be replaced, as much as possible, by a carcass-only trade. Animals going from farm to slaughter may pass through a market. Based on data from the Meat and Livestock Commission, Murray *et al.* (2000) reported that, in the UK in 1996, 56% of cattle, 65% of sheep and 5% of pigs passed through a livestock auction market. In a study of 16,000 sheep travelling to slaughter in South-west England, the median journey duration was 1.1 h, with very few journeys of more than 5 h, and when the sheep went directly from farm to abattoir 7.8 h, with over a third of journeys 10–17 h, when they went via a livestock market (Murray *et al.*, 2000). Fewer animals are going to auctions in 2006 but the exact number is not known.

The first stage of a journey is the selection of animals that will travel and there should be inspection of these animals to check that they are fit to travel. Animals are prepared for the journey and this preparation will depend on the species and the length of the journey envisaged. For shorter journeys preparation can include fasting before collection and possibly movement away from the main herd to protect its health status. For longer journeys, where watering and feeding will be necessary on the vehicle, it can be an advantage to collect the animals involved 2–3 days before the transport, so that they can be prepared for the journey and become accustomed to the feed that will be offered en route.

The animals then have to be loaded on to the transport vehicle. This may be a road or rail vehicle or a boat. Loading is discussed later in relation to welfare. During transport, animals gradually relax to some extent as they start to become accustomed to the new environment so there is some recovery from the stress of loading. Animal comfort during transport is highly dependent on vehicle design, driving technique and the roads being traversed. Requirements for vehicles will therefore depend on the length of the journey. All things being equal, the demands for transport vehicles will become more stringent as transport distances increase and weather conditions become more extreme, whether this is very cold or very hot weather. Drivers should always be conversant with the needs of animals during transport and should receive formal training, unless previous experience can be proven for the type of transport envisaged.

During transport, offloading and on-loading of animals for rest periods, feeding and watering is often recommended. However, it may increase stress levels and the risk of injury. Moreover, there will be a risk of spreading disease if the animals come into contact with other animals. Except in the circumstance where there can be a substantial period lasting a day or more, when the animals can rest off the vehicle, a vehicle of such a standard that animals can remain on it during the resting, watering or feeding period may be advantageous.

At the end of the journey to slaughter, animals are unloaded at the slaughterhouse. Good facilities are required for this. A period of lairage may occur before slaughter. For most species, welfare is better if any lairage period is very short.

The vehicles used

Horses and cattle are normally carried in vehicles with one tier but pigs and sheep may be carried in two- or three-tier vehicles. Poultry and rabbits are usually carried in crates. These may be stackable crates, of such a size that a person can lift one of them, or may be modular units that have to be lifted with a forklift vehicle. On the vehicle, there should be air spaces between the rows of crates or modules.

Some vehicles are air-conditioned, some have well-designed openable areas on the sides for ventilation, some have poorly designed possibilities for ventilation, and some of the simplest vehicles have open bars on the sides. The latter can provide good ventilation but little protection from injury in crash situations or from poor weather. In developed countries and in some developing countries, all but the worst vehicles provide some shade and shelter from rain or other inclement weather.

The suspension system in animal transport vehicles varies from very good to negligible. The provision for loading animals also varies greatly. Some vehicles are adapted for use with well-designed ramps while others have hydraulic lifts on tailgates or floors. Many have very steep loading ramps that cause poor welfare in all animals loaded.

Factors Which Can Result in Poor Welfare During Animal Handling and Transport

In the section below, major factors that result in poor welfare are underlined. People are sometimes cruel to one another but generally believe that other people are aware and sentient and so are likely to feel some guilt if they have been cruel. Non-human animals are regarded as aware and sentient by some people but as objects valued only according to their use by others (Broom, 2003, 2006b). Hence, there is a wide range of attitudes to animals and these have major consequences for animal welfare. During handling and transport, these attitudes may result in one person causing high levels of stress in the animals while another person doing the same job may cause little or no stress. People may hit animals and cause substantial pain and injury because they are trying to do the work very quickly, or because they do not consider that the animals are subject to pain and stress, or because of lack of knowledge about animals and their welfare. Training of staff can substantially alter attitudes to, and treatment of, animals.

Laws can have a significant effect on the ways in which people manage animals. Within the European Union, the Council Regulation (EC) No 1/2005 'On the protection of animals during transport and related operations' takes up some of the recommendations of the EU Scientific Committee on Animal Health and Animal Welfare Report 'The welfare of animals during transport (details for horses, pigs, sheep and cattle)' (March, 2002) and of the European Food Safety Authority 'Report on the welfare of animals during transport' (2004) which deals with the other species. Laws have effects on animal welfare provided that they are enforced and the mechanisms for enforcement within EU Member States are the subject of discussion in 2006. Adequate enforcement requires training and there is variation among countries in both training and willingness to enforce laws about animal welfare during transport (see Chapter 5, this volume). The existence of the OIE Guidelines on animal transport should lead to greater uniformity of laws and of their enforcement.

Codes of practice can also have significant effects on animal welfare during transport. The most effective of these, sometimes just as effective as laws, are retailer codes of practice since retail companies need to protect their reputation by enforcing adherence to their codes (Broom, 2002).

Some animals are much better able to withstand the range of environmental impacts associated with handling and transport than are other animals. This can be because of genetic differences, associated with the breed of the animal or with selection for production characteristics. Differences among individuals in coping ability also depend on housing conditions and the extent and nature of contact with humans and conspecifics during rearing. If pigs are handled gently on 2–3 days during development, they are easier to handle and their welfare is better during transport.

Since physical conditions within vehicles during transport can affect the extent of stress in animals, the selection of an appropriate vehicle for transport is important in relation to animal welfare. Similarly, the design of loading and unloading facilities is of great importance. Although seemingly far removed, the person who designs the vehicle and facilities has a substantial influence, as does the person who decides which vehicle or equipment to use.

Before a journey starts, there must be decisions about the stocking density of animals on the vehicle and the grouping and distribution of animals on the vehicle. If there is withdrawal of food from animals to be transported, this can lead to poor welfare. For all species, tying of animals on a moving vehicle can lead to major problems and for cattle and pigs any mixing of animals can cause very poor welfare.

The behaviour of drivers towards animals while loading and unloading and the way in which people drive vehicles are affected by the method of payment. If people are paid more if they load or drive fast, welfare could be worse, so such methods of payment should not be permitted (Broom, 2000). Payment of handling and transport staff at a higher rate if the incidences of injury and poor meat quality are low improves welfare. Insurance against bad practice resulting in injury or poor meat quality should not be permitted.

All the factors mentioned so far should be taken into account in the procedure of planning for transport. Planning should also take account of temperature, humidity, weather conditions and the risks of disease transmission. Disease is a major cause of poor welfare in transported animals and has significant consequences for trade in animals and animal products (see Chapter 3, this volume). Planning of routes should take account of the needs of the animals for rest, food and water. Drivers or other persons responsible should have plans for emergencies including a series of emergency telephone numbers to use to obtain veterinary assistance in the event of injury, disease or other welfare problems during a journey.

The methods used during handling, loading and unloading can have a great effect on animal welfare. The quality of driving can result in very few problems for the animals or in poor welfare because of difficulty in maintaining balance, motion sickness, injury, etc. The actual physical conditions, such as temperature and humidity may change during a journey and require action on the part of the person responsible for the animals. A journey of long duration will have a much greater risk of poor welfare and some durations inevitably lead to problems. Hence, good monitoring of the animals with inspections of adequate frequency, and in conditions which allow thorough inspection, is important.

Assessing Welfare

A variety of welfare indicators, which can be used to assess the welfare of animals that are being handled or transported, are listed in Table 7.2. Some of these measures are of short-term effects while others are more relevant to prolonged problems. Where animals are transported to slaughter it is mainly the measures of short-term effects such as behavioural aversion or increased heart rate, which are used but some animals are kept for a long period after transport and measures such as increased disease incidence or suppression of normal development give information about the effects of the journey on welfare. When animals are transported, there may be various stressors that affect them and the response of the animals

Table 7.2. Generally used measures of welfare. Details of these and other measures may be found in Broom (1998), Fraser and Broom (1997) and Broom and Johnson (2000). (From Broom, 2000.)

Physiological indicators of pleasure
Behavioural indicators of pleasure
Extent to which strongly preferred behaviours can be shown
Variety of normal behaviours shown or suppressed
Extent to which normal physiological processes and anatomical development are possible
Extent of behavioural aversion shown
Physiological attempts to cope
Immunosuppression
Disease prevalence
Behavioural attempts to cope
Behaviour pathology
Brain changes, e.g. those indicating self-narcotization
Body damage prevalence
Reduced ability to grow or breed
Reduced life expectancy

depends on the duration and intensity of these stressors (Fazio and Ferlazzo, 2003). The factors may interact in an additive or multiplicative way to determine the magnitude of the total effect on the animal (Broom, 2001a).

[AU4] Behavioural measures

Changes in behaviour are obvious indicators that an animal is having difficulty coping with handling or transport. Some of these help to show which aspect of the situation is aversive. The animal may stop moving forward, freeze, back off, run away or vocalize. The occurrence of each of these can be quantified in comparisons of responses to different races, loading ramps, etc. Examples of behavioural responses such as cattle stopping when they encounter dark areas or sharp shadows in a race and pigs freezing when hit or subjected to other disturbing situations may be found in Grandin (1980, 1982, 1989, 2000).

Certain behavioural responses are often shown in painful or otherwise unpleasant situations. Their nature and extent vary from one species to another according to the selection pressures, which have acted during the evolution of the mechanisms controlling behaviour. Human approach and contact may elicit antipredator behaviour in farm animals. However, with experience of handling, these responses can be greatly reduced in cattle (Le Neindre *et al.*, 1996). Social species, which can collaborate in defence against predators, such as pigs or man, vocalize a lot when caught or hurt. Species which are unlikely to be able to defend themselves, such as sheep, vocalize far less when caught by a predator, probably because such an extreme response merely gives information to the predator that the animal attacked is severely injured and hence unlikely to be able to escape. Cattle can also be relatively undemonstrative when hurt or severely disturbed. Human observers sometimes wrongly assume that an animal that is not squealing is not hurt or disturbed by what is being done to it. In some cases, the animal is showing a freezing response and in most cases, physiological measures must be used to find out the overall response of the animal.

Within species, individual animals may vary in their responses to potential stressors. The *coping strategy* adopted by the animal can have an effect on responses to the transport and lairage situation. For example, Geverink *et al.* (1998) showed that those pigs which were most aggressive in their home pen were also more likely to fight during pre-transport or pre-slaughter handling but pigs which were driven for some distance prior to transport were less likely to fight and hence cause skin damage during and after transport. This fact can be used to design an on-farm test, which reveals whether or not the animals are likely to be severely affected by the transport situation (Lambooij *et al.*, 1995).

The procedures of loading and unloading animals into and out of transport vehicles can have very severe effects on the animals and these effects are revealed in part by behavioural responses. Species vary considerably in their *responses to loading procedures*. Any animal which is injured or frightened by people during the procedure can show extreme responses. However, using efficient and careful loading procedures, sheep and cattle can be loaded without severe effects, although pigs and poultry always show more disturbance. Broom *et al.* (1996) and Parrott *et al.* (1998b) found that sheep show largely physiological responses and these are associated with the unfamiliar situation encountered in the vehicle rather than the loading procedure.

Once journeys start, some species of farm animals explore the compartment in which they are placed and try to find a suitable place to sit or lie down. Sheep and cattle try to lie down if the situation is not disturbing but stand if it is. After a period of acclimatization of sheep and cattle to the vehicle environment, during which time sheep may stand for 2–4 h looking around at intervals and cattle may stand for rather longer, most of the animals will lie down if the opportunity arises. Pigs lie down much more rapidly. Unfortunately for the animals, many journeys involve so many lateral movements or sudden brakings or accelerations that the animals cannot lie down.

An important behavioural measure of welfare in experimental studies when animals are transported is the amount of fighting. For example, when male adult cattle are mixed during transport or in lairage, they may fight and this behaviour can be recorded directly (Kenny and Tarrant, 1987). Calves of 6 months of age may also fight (Trunkfield and Broom, 1991). The recording of such behaviour should include the occurrence of threats as well as the contact behaviours that might cause injury.

A further valuable behavioural method for welfare assessment of farm animals during handling and transport involves using the fact that the animals remember aversive situations in experimentally repeated exposures to such situations. Any stock-keeper will be familiar with the animal, which refuses to go into a crush after having received painful treatment there in the past or hesitates about passing a place where a frightening event such as a dog threat occurred once before. These observations give us information about the welfare of the animal in the past as well as at the present time. If the animal tries not to return to a place where it had an experience then that experience was clearly aversive. The greater the reluctance of the animal to return, the greater the previous aversion must have been. This principle has been used by Rushen (1986a,b) in studies with sheep. Sheep, which were driven down a race to a point where gentle handling occurred, traversed the race as rapidly or more rapidly on a subsequent day. Sheep, which were subjected to shearing at the end of the race on the first day, were harder to drive down the race subsequently and those subjected to electro-immobilization at the end of the race were very difficult to drive down the race on later occasions. Hence, the degree of difficulty in driving and the delay before the sheep could be driven down the race are measures of the current fearfulness of the sheep and this in turn reflects the aversiveness of the treatment when it was first experienced.

Some behavioural measures are clear indicators that there will be a long-term effect on the animal, which will harm it, so they indicate stress. As explained later, other behavioural measures provide evidence of good or poor welfare but not necessarily of stress.

Physiological measures

The physiological responses of animals to adverse conditions, such as those which they may encounter during handling and transport, will be affected by the anatomical and physiological constitution of the animal as mentioned later. Some physiological measures are detailed in Table 7.3 and described in detail below.

Whenever physiological measurement is to be interpreted it is important to ascertain the *basal level* for that measure and how it fluctuates over time (Broom, 2000). For example, plasma cortisol levels in most species vary during the day and tend to be higher during the morning than during the afternoon. A decision must be taken for each measure concerning whether the information required is the difference from baseline or the absolute value. For small effects, e.g. a 10% increase in heart rate, the difference from baseline is the key value to use. The large effects where the response reaches the maximal possible level, for example, cortisol in plasma in very frightening circumstances, the absolute value should be used. In order to explain this, consider an animal severely frightened during the morning and showing an increase from a rather high baseline of 160 nmol/l but in the afternoon showing the same maximal response which is 200 nmol/l above the lower afternoon baseline. It is the actual value which is important here rather than a difference whose variation depends on baseline fluctuations. In many studies, the value obtained after the treatment studied can usefully be compared with the maximum possible response for that measure. A very frightened animal may show the highest response of which it is capable.

Heart rate can decrease when animals are frightened but in most farm animal studies, tachycardia, increase in heart rate, has been found to be associated with disturbing situations. Heart rate increase is not just a consequence of increased activity; heart rate can be increased in preparation for an expected future flight response. Baldock and Sibly (1990) obtained basal levels for heart rate during a variety of activities by sheep and then took account of these when calculating responses to various treatments. Social isolation caused a substantial response but the greatest heart rate increase occurred when the sheep were approached by a man with a dog. The responses to handling and transport are clearly much lower if the sheep have previously been accustomed to human handling. Heart rate is a useful measure of welfare but only for short-term problems such as those encountered

Table 7.3. Commonly used physiological indicators of poor welfare during transport. (Modified after Knowles and Warriss, 2000.)

Stressor	Physiological variable
	Measured in blood or other body fluids
Food deprivation	↑ FFA, ↑ ß-OHB, ↓ glucose, ↑ urea
Dehydration	↑ Osmolality, ↑ total protein, ↑ albumin, ↑ PCV
Physical exertion	↑ CK, ↑ lactate
Fear, lack of control	↑ Cortisol, ↑ PCV
Motion sickness	↑ Vasopressin
	Other measures
Fear, physical effects	↑ Heart rate, heart rate variability ↑, ↑ respiration rate
Hypothermia/hyperthermia	Body temperature, skin temperature

FFA, free fatty acids; ß-OHB, ß-hydroxybutyrate; PCV, packed cell volume; CK, creatine kinase.

by animals during handling, loading on to vehicles and certain acute effects during the transport itself. However, some adverse conditions may lead to elevated heart rate for quite long periods. Parrott *et al.* (1998a) showed that heart rate increased from about 100 beats per min to about 160 beats per min when sheep were loaded on to a vehicle and the period of elevation of heart rate was at least 15 min. During transport of sheep, heart rate remained elevated for at least 9 h (Parrott *et al.*, 1998b). Heart rate variability has also been found to be a useful welfare indicator in cattle and other species (van Ravenswaaij *et al.*, 1993).

Observation of animals can provide information about physiological processes in animals without any attachment of recording instruments or sampling of body fluids. *Breathing rate* can be observed directly or from good-quality video recordings. The metabolic rate and level of muscular activity are major determinants of breathing rate but an individual animal, which is disturbed by events in its environment, may suddenly start to breathe fast. *Muscle tremor* can be directly observed and is sometimes associated with fear. *Foaming at the mouth* can have a variety of causes, so care is needed in interpreting the observations, but its occurrence may provide some information about welfare.

Changes in the *adrenal medullary hormones* adrenaline (epinephrine) and noradrenaline (norepinephrine) occur very rapidly and measurements of these hormones have not been used much in assessing welfare during transport. However, Parrott *et al.* (1998a) found that both hormones increased more during loading of sheep by means of a ramp than by loading with a lift.

Adrenal cortex changes occur in most of the situations, which lead to aversion behaviour or heart rate increase but the effects take a few minutes to be evident and they last for 15 min to 2 h or a little longer. An example comes from work on calves (Kent and Ewbank, 1986; review by Trunkfield and Broom, 1990; Trunkfield *et al.*, 1991). Plasma or saliva glucocorticoid levels gave information about treatments lasting up to 2 h but were less useful for journeys lasting longer than this.

Saliva cortisol measurement is useful in cattle. In the plasma, most cortisol is bound to protein but it is the free cortisol, which acts in the body. Hormones such as testosterone and cortisol can enter the saliva by diffusion in salivary gland cells. The rate of diffusion is high enough to maintain an equilibrium between the free cortisol in plasma and in saliva. The level is ten or more times lower in saliva but stimuli which cause plasma cortisol increases also cause comparable salivary cortisol increases in humans (Riad-Fahmy *et al.*, 1982), sheep (Fell *et al.*, 1985), pigs (Parrott *et al.*, 1989) and some other species. The injection of pilocarpine and sucking of citric acid crystals, which stimulate salivation, has no effect on the salivary cortisol concentration. However, any rise in salivary cortisol levels following some stimulus is delayed a few minutes as compared with the comparable rise in plasma cortisol concentration.

Animals, which have substantial adrenal cortex responses during handling and transport, show increased body temperature (Trunkfield *et al.*, 1991). The increase is usually of the order of 1°C but the actual value at the end of a journey will depend upon the extent to which any adaptation of the initial response has occurred. The body temperature can be recorded during a journey with implanted or superficially attached temperature monitors linked directly or telemetrically to a data storage system. Parrott *et al.* (1999) described deep body temperature in eight sheep.

When the animals were loaded into a vehicle and transported for 2.5 h, their body temperatures increased by about 1°C and in males were elevated by 0.5°C for several hours. Exercise for 30 min resulted in a 2°C increase in core body temperature which returned rapidly to baseline when the exercise finished. It would seem that prolonged increases in body temperature are an indicator of poor welfare.

The measurement of oxytocin, although a useful indicator in the longer term, has not been of particular value in animal transport studies (e.g. Hall *et al.*, 1998). [AU5] However, plasma beta-endorphin levels have been shown to increase during loading (Bradshaw *et al.*, 1996b). The release of corticotrophin releasing hormone (CRH) in the hypothalamus is followed by release of pro-opiomelanocortin (POMC) in the anterior pituitary, which quickly breaks down into components, including adrenocorticotrophic hormone (ACTH) which travels in the blood to the adrenal cortex and beta-endorphin. A rise in plasma beta-endorphin often accompanies ACTH increases in plasma but it is not yet clear what its function is. Although beta-endorphin can have analgesic effects via mu-receptors in the brain, this peptide hormone is also involved in the regulation of various reproductive hormones. Measurement of beta-endorphin levels in blood is useful as a back-up for ACTH or cortisol measurement.

Creatine kinase is released into the blood when there is muscle damage, e.g. bruising, and when there is vigorous exercise. It is clear that some kinds of damage that effect welfare result in creatine kinase release, so it can be used in conjunction with other indicators as a welfare measure. Lactate dehydrogenase (LDH) also increases in the blood after muscle tissue damage but increases can occur in animals whose muscles are not damaged. Deer, which are very frightened by capture, show large LDH increases (Jones and Price, 1992). The isoenzyme of LDH, which occurs in striated muscle (LDH5), leaks into the blood when animals are very disturbed so the ratio of LDH5 to total LDH is of particular interest.

On long journeys animals are generally unable to drink for many times longer than the normal interval between drinking bouts. This lack of control over interactions with the environment may be disturbing to the animals and there are also likely to be physiological consequences. The most obvious and straightforward way to assess this is to measure the osmolality of the blood (Broom *et al.*, 1996). When food reserves are used up there are various changes evident in the metabolites present in the blood. Several of these, for example beta-hydroxy butyrate, can be measured and indicate the extent to which the food reserve depletion is serious for the animal. If chickens reared for meat production were deprived of food for 10 h prior to 3 h of transport, when compared with undeprived birds, their plasma had higher thyroxine and lower tri-iodothyronine, triglyceride, glucose and lactate concentrations, indicating negative energy balance and poor welfare. Another measure, which gives information about the significance for the animal of food deprivation, is the delay since the last meal. Most farm animals are accustomed to feeding at regular times and if feeding is prevented, especially when high rates of metabolism occur during journeys, the animals will be disturbed by this. Behavioural responses when allowed to eat or drink (e.g. Hall *et al.*, 1997) also give important information about problems of deprivation.

The haematocrit, a count of red blood cells, is altered when animals are transported. If animals encounter a problem, such as those which may occur when they are handled or transported, there can be a release of blood cells from the spleen and a higher cell count (Parrott *et al.*, 1998b). More prolonged problems, however, are likely to result in reduced cell counts (Broom *et al.*, 1996).

Increased adrenal cortex activity can lead to immunosuppression. One or two studies in which animal transport affected T-cell function are reviewed by Kelley (1985), but such measurements are likely to be of most use in the assessment of more long-term welfare problems. The ability of the animal to react effectively to antigen challenge will depend upon the numbers of lymphocytes and the activity and efficiency of these lymphocytes. Measures of the ratios of white blood cells, for example the heterophil to lymphocyte ratio, are affected by a variety of factors but some kinds of restraint seem to affect the ratio consistently so they can give some information about welfare. Studies of T-cell activity, e.g. *in vitro* mitogen stimulated cell proliferation, give information about the extent of immunosuppression resulting from the particular treatment. If the immune system is working less well because of a treatment, the animal is coping less well with its environment and the welfare is poorer than in an animal, which is not immunosuppressed. Examples of the immunosuppressive effect of transport are the reduction in four different lymphocyte subpopulations after 24 h of transport in horses (Stull *et al.*, 2004) and the reduction in phytohaemagglutinin stimulated lymphocyte proliferation in *Bos indicus* steers during the 6 days after they had been transported for 72 h (Stanger *et al.*, 2005).

As with behavioural measures, some physiological measures are good predictors of an earlier death or of reduced ability to breed while others are not measures of stress because the effect will be brief or slight.

Carcass and mortality measures

Measures of body damage, major disease condition or of increased mortality are indicators of long-term adverse effects on animal welfare. A bruise or cut will result in a slight or a substantial degree of poor welfare depending on its magnitude. Death during handling and transport is usually preceded by a period of poor welfare. Mortality records during journeys are often the only records, which give information about welfare during the journey and the severity of the problems for the animals are often only too clear from such records.

Carcass measures are discussed in detail in Chapter 4, this volume.

Experimental procedures for the scientific study of welfare during transport.

As Hall and Bradshaw (1998) explain, information on the stress effects of transport is available from five kinds of study:

1. Studies where transport, not necessarily in conditions representative of commercial practice, was used explicitly as a stressor to evoke a physiological response of particular interest (Smart *et al.*, 1994; Horton *et al.*, 1996);
2. Uncontrolled studies with physiological and behavioural measurements being made before and after long or short commercial or experimental journeys (Becker *et al.*, 1985; Dalin *et al.*, 1988, 1993; Becker *et al.*, 1989; Knowles *et al.*, 1994);

3. Uncontrolled studies during long or short commercial or experimental journeys (Lambooij, 1988; Hall, 1995);
4. Studies comparing animals that were transported with animals that were left behind to act as controls (Nyberg *et al.*, 1988; Knowles *et al.*, 1995); and
5. Studies where the different stressors that impinge on an animal during transport were separated out either by experimental design (Bradshaw *et al.*, 1996c; Broom *et al.*, 1996; Cockram *et al.*, 1996) or by statistical analysis (Hall *et al.*, 1998c).
Each of these methods is of value because some are carefully controlled but less representative of commercial conditions while others show what happens during commercial journeys but are less well controlled.

Discussion of Some Key Factors

Animal genetics and transport

Cattle and sheep have been selected for particular breed characteristics for hundreds of years. As a consequence, there may be differences between breeds in how they react to particular management conditions. For example, Hall *et al.* (1998) [AU6] found that introduction of an individual sheep to three others in a pen resulted in a higher heart rate and salivary cortisol concentration if it was of the Orkney breed than if it was of the Clun Forest breed. The breed of animal should be taken into account when planning transport.

Farm animal selection for breeding has been directed especially towards maximizing productivity. In some farm species there are consequences for welfare of such selection (Broom, 1994, 1999). Fast-growing broiler chickens may have a high prevalence of leg disorders and Belgian Blue cattle may be unable to calve unaided or without the necessity for Caesarean section. Some of these effects may affect welfare during handling and transport. Some beef cattle, which have grown fast, have joint disorders, which result in pain during transport and some strains of high-yielding dairy cows are much more likely to have foot disorders. Modern strains of dairy cows, in particular, need much better conditions during transport and much shorter journeys if their welfare is not to be poorer than the more traditional breeds of dairy cow used 30 years ago.

Rearing conditions, experience and transport

If animals are kept in such a way that they are very vulnerable to injury when handled and transported, this must be taken into account when transporting them or the rearing conditions must be changed. A notable example of such an effect is the osteopenia and vulnerability to broken bones, which is twice as high in hens in battery cages than in hens which are able to flap their wings and walk around (Knowles and Broom, 1990). Calves are much more disturbed by handling and transport if they are reared in individual crates than if they are reared in groups, presumably because of lack of exercise and absence of social stimulation in the rearing conditions (Trunkfield *et al.*, 1991).

Human contact prior to handling and transport is also important. If young cattle have been handled for a short period just after weaning they are much less disturbed by the procedures associated with handling and transport (Le Neindre *et al.*, 1996). All animals can be prepared for transport by appropriate previous treatment.

Mixing social groups and transport

If pigs or adult cattle are taken from different social groups, whether from the same farm or not, and are mixed with strangers just before transport, during transport or in lairage there is a significant risk of threatening or fighting behaviour (McVeigh and Tarrant, 1983; Guise and Penny, 1989; Tarrant and Grandin, 2000). The glycogen depletion associated with threat, fighting or mounting often results in dark firm dry meat, injuries such as bruising and associated poor welfare. The problem is sometimes very severe, in welfare and economic terms, but is solved by keeping animals in groups with familiar individuals rather than mixing strangers. Cattle might be tethered during loading but should never be tethered when vehicles are moving because long tethers cause a high risk of entanglement and short tethers cause a high risk of cattle being hung by the neck. Mixing of pigs on vehicles causes a substantial increase in aggression (Shenton and Shackleton, 1990) and cortisol levels in transported pigs were higher if there was mixing of pigs from different origins (Bradshaw *et al.*, 1996b).

Handling, loading, unloading and welfare

[AU7] Many studies have shown that loading and unloading are the most stressful part of transport (Hall and Bradshaw, 1998). The physiological changes indicative of stress occur at loading and last for the first few hours of transport. Then, the stress response can gradually decline, depending on driving quality and other factors, as the animals become accustomed to transport (Knowles *et al.*, 1995; Broom *et al.*, 1996). The large effect that loading may have on the welfare of the animals results from a combination of several stressors that impinge upon the animals in a very short period of time. One of these stressors is forced physical exercise as the animals are moved into the vehicle. Physical exertion is particularly important when animals have to climb steep ramps. Second, psychological stress is caused by the novelty of being moved into unknown surroundings. Also, loading requires close proximity to humans and this can cause fear in animals that are not habituated to human contact. Finally, pain may result from mishandling of animals at loading. For example, beating or poking animals with a stick, especially in sensitive areas like the eyes, mouth, anogenital regions or belly and catching sheep by the fleece will cause pain. The use of electric goads will be painful as well.

The slope of ramp is an important aspect when loading or unloading animals. This can be measured in degrees (e.g. 20°) or as percentage gradient (e.g. 20%). The percentage gradient indicates the increase in height in metres over 100 horizontal metres distance. For example, a gradient of 20% means a slope of 20 in 100 (i.e. 1 in 5) and is equivalent to 11°.

There are important differences between species in their response to handling and loading and these should be taken into account when choosing appropriate loading procedures. For example, pigs have more difficulties than sheep or cattle in negotiating steep ramps.

Despite all these differences between and within species, several general recommendations can be made. For example, even illumination and gently curved races without sharp corners facilitate the movement of the animals. Non-slip flooring and good drainage to prevent pooling of water are also important. As animals prefer to walk slightly uphill rather than downhill, floors should be flat or slope upwards. On the other hand, however, ramps should not be too steep (Grandin, [AU8] 2001), i.e. not more than 20°. If the floor of the loading ramp is not slippery, there still remain differences between species in the steepness of slope which they can climb or descend safely.

Well-trained and experienced stock-people know that cattle can be readily moved from place to place by human movements that take advantage of the animal's flight zone, i.e. the point during an approach when the animal will flee (Kilgour and Dalton, 1984; Grandin, 2000). Cattle will move forward when a person enters the flight zone at the point of balance and can be calmly driven up a race by a person entering the flight zone and moving in the opposite direction to that in which the animals are desired to go. Handling animals without the use of sticks or electric goads results in better welfare and less risk of poor carcass quality.

The handling and loading of poultry and rabbits is very different from that for the larger mammals. Chickens reared for meat production are often collected by human catching teams and sometimes by broiler collector machines. The welfare is almost always worse when human catching is involved (Duncan *et al.*, 1986). Laying hens are usually also collected and put into crates or modules by people and show substantial adrenal responses when caught. Bone breakage is common in hens during catching, especially if the birds have had insufficient exercise because they have been kept in small cages, or have leg disorders, as in fast-growing broiler meat chicken strains.

Thorough knowledge of animal behaviour and the presence of appropriate facilities are important for good welfare during handling and loading. This point is stressed in the OIE Guidelines.

Temperature and other physical conditions during transport

Extremes of temperature can cause very poor welfare in transported animals. Exposure to temperatures below freezing has severe effects on small animals including domestic fowl. However, temperatures that are too high are a commoner cause of poor welfare with poultry, rabbits and pigs being especially vulnerable. For example, De la Fuente *et al.* (2004) found that plasma cortisol, lactate, glucose, creatine kinase, lactate dehydrogenase and osmolarity were all higher in warmer summer conditions than in cooler winter conditions in transported rabbits. In each of these species, and particularly in chickens reared for meat production, stocking density must be reduced in temperatures of 20°C or higher or there is a substantial risk of high mortality and poor welfare.

A period of rest during a journey can be important to animals, especially those that are using up more than the usual amount of energy during the journey because of the position that they have to adopt or because they have to show prolonged or intermittent adrenal responses, which mobilize energy reserves. One way of judging how tired animals become during a journey is to observe how strongly they prefer to rest after the journey. Another way is to assess any emergency responses or adverse effects on their ability to cope with pathogen challenge. For example, Oikawa *et al.* (2005) found that horses on a 1500 km journey showed less adrenal response and less sign of harmful inflammatory responses if they had longer rests and had their pen on the vehicle cleaned during the journey.

Vehicle driving methods, stocking density and welfare

When humans are driven in a vehicle, they can usually sit on a seat or hold on to some fixture. Cattle standing on four legs are much less well able to deal with accelerations such as those caused by swinging around corners or sudden braking. Cattle always endeavour to stand in a vehicle in such a way that they brace themselves to minimize the chance of being thrown around and avoid making contact with other individuals. They do not lean on other individuals and are substantially disturbed by too much movement or too high a stocking density. In a study of sheep during driving on winding or straight roads, Hall *et al.* (1998c) found that [AU9] plasma cortisol concentrations were substantially higher on winding than on straight roads. Tarrant *et al.* (1992) studied cattle at a rather high, an average and a low commercial stocking density and found that falls, bruising, cortisol and creatine kinase levels all increased with stocking density. Careful driving and a stocking density which is not too high are crucial for good welfare.

The amount of space allowed for an animal during transport is one of the most important factors affecting animal welfare. In general, smaller space allowances lead to lower unit costs of transport since more animals can be carried in a vehicle of any particular size. Space allowances have two components. The first component is the floor area available to the animal to stand or lie in. This equates to what is usually referred to as stocking density. The second component is the height of the compartment in which the animal is carried. With multi-decked road vehicles, this may be especially important because there are practical constraints on the overall maximum height of the vehicles, for example to enable them to pass under bridges. There is thus a commercial pressure to reduce the vertical distance between decks (deck height), and therefore, the volume of space above the animal's heads. This reduction may adversely affect adequate ventilation of the inside of the compartment in which the animals are held.

Absolute minimum space allowances are determined by the physical dimensions of animals, but this will not be sufficient to allow for good welfare. Acceptable minimum allowances will be dependent on other factors as well. These include the ability of the animals to thermoregulate effectively, ambient conditions, particularly environmental temperature and whether the animals should be allowed enough space to lie down if they so wish. Whether animals want to lie down may depend on journey length, transport conditions, especially whether it is comfortable to do so and the care exercised in driving the vehicle and its suspension characteristics in relation to the quality of the road surface. A very important consideration in establishing practical minimum space requirements is if the animals are to be rested, watered and fed on the vehicle. Resting, watering and feeding on the vehicle will require lower stocking densities to enable the animals to access feed and water. Space allowances may need to be greater if vehicles are stationary for prolonged periods to promote adequate ventilation, unless this is facilitated and controlled artificially.

When four-legged animals are standing on a surface subject to movement, such as a road vehicle, they position the feet outside the normal area under the body in order to help them to balance. They also need to take steps out of this normal area if subjected to accelerations in a particular direction. Hence, they need more space than if standing still. When adopting this position and making these movements on a moving vehicle, cattle, sheep, pigs and horses make considerable efforts not to be in contact with other animals or the sides of the vehicle. Provided that vehicles are driven well, up to a space allowance larger than that used in animal transport, the greater the space allowance, the better the welfare of the animals. However, if vehicles are driven badly and animals are subjected to the substantial lateral movement that results from driving too fast around corners, or to violent braking, close packing of animals may result in less injury to them. The best practice is to drive well and stock in a way, which gives space for the animals to adopt the standing or lying position, which is least stressful to them.

A separate problem, which is linked to space allowance, is aggression or potentially harmful mounting behaviour. Pigs and adult male cattle may threaten one another, fight and injure one another. This results in poor welfare and increased percentage of DFD meat. Rams and some horses may also fight. Such fighting is minimized or avoided by keeping animals in the social groups in which they lived on the farm or by separating animals that might fight. Groups of male animals may mount one another, sometimes causing injuries in doing so. At very high stocking densities, fighting and mounting is more difficult and injuries due to such behaviour may be reduced. However, such problems can be solved by good management of animals and keeping animals at an artificially high stocking density in an attempt to immobilize them will result in poor welfare.

Floor space allowances need to be defined in unambiguous terms. In particular, stocking densities must be defined as m^2 floor area per animal of a specified live weight, e.g. ($m^2/100\,kg$), or kg live weight per m^2 floor area (kg/m^2). Stocking rates, such as m^2 per animal (m^2/animal), are not an acceptable way of defining floor space requirements since they take no account of variation in animal weight. Definitions of acceptable space allowances must consider the whole range of animal sizes (live weights) to be encountered. A problem is that information applicable to very small or very large animals is sometimes not available. Moreover, the relationship between minimum acceptable space allowance and animal weight is often not linear. Determining appropriate minimum acceptable space allowances for transported animals relies on several types of evidence. These include evidence based on first principles using measurements of the dimensions of animals, evidence based on behavioural observations of animals during real or simulated transport conditions and evidence based on the measurement of indices of adverse effects of transport. An example of the latter kind of evidence would be the amount

Table 7.4. Recommended minimum floor space allowances – examples.

Species	Body weight (kg)	Travel duration	Floor space allowance
Pigs	100 kg	Up to 8 h	0.42 m^2
		More than 8 h	0.60 m^2
Sheep – shorn	40 kg	Up to 4 h	0.24 m^2
		4–12 h	0.31 m^2
		More than 12 h	0.38 m^2
Sheep – unshorn	40 kg	Up to 4 h	0.29 m^2
		4–12 h	0.37 m^2
		More than 12 h	0.44 m^2
Cattle	500 kg	Up to 12 h	1.35 m^2
		More than 12 h	2.03 m^2

of bruising on the carcass or the activity of enzymes such as creatine kinase (CK) in the blood that indicate bruising or severe disturbance.

For an animal of the same shape, and where body weight is W, linear measurements will be proportional to the cube root of W ($\sqrt[3]{W}$). The area of the surface of the animal will be proportional to the square of this linear measure ($\left(\sqrt[3]{W}\right)^2$). Algebraically this is equivalent to the cube root of the weight squared ($\sqrt[3]{W^2}$), or weight to the power of two-thirds ($W^{0.67}$). The minimum acceptable area for all types of animal is:

$$A = 0.021\ W^{0.67}$$

where A is the minimum floor area required by the animal in m^2 and W is the weight of the animal in kg. The number in the equation (0.021) is a constant for a given shape of the animal, in particular the ratio of its body length to its body width.

As a result of a review of the literature on the effects of space allowance on welfare, the EU SCAHAW (2002) recommended equations for calculating space allowance for pigs, sheep and cattle and examples of the results of such calculations are as shown in Table 7.4. Similarly, the EFSA Scientific panel AHAW (2004) recommended equations to be used for the calculation of space allowances for other farm animal species. In many countries, much less space per animal is provided on vehicles.

Feeding and watering during transport

Drinking is stimulated when the lack of water causes the blood concentration to increase. Animals vary according to species in how often they drink in a 24 h period and horses may only drink once or twice a day. It is difficult to provide water continuously and many animals will not drink during vehicle movement, so frequent stops of sufficient duration for drinking may be necessary if adequate drinking is to occur when water is provided on the vehicle.

Research aiming to characterize progressively dehydration, stress responses and water consumption patterns of horses transported long distances in hot weather and to estimate recovery time after 30 h of commercial transport concluded that transporting healthy horses for more than 24 h during hot weather and without water will cause severe dehydration; transport for more than 28 h, even with periodic access to water, will likely be harmful due to increasing fatigue (Friend, 2000).

[AU10] Brown *et al.* (1999) compared constant transport for 8, 16 and 24 h without resting periods or watering/feeding and observed the need for pigs to drink and feed during a 6 h lairage period. The results showed that even though the environmental temperatures were relatively mild (14–20°C), all pigs drank and ate during the lairage period and that in particular pigs transported for 8 h, ate and drank immediately after arrival before they rested. It is clear that they had already become dehydrated and hungry. Sheep often do not eat during vehicle movement. Nevertheless, after 12 h of deprivation sheep become very eager to eat (Knowles, 1998).

As for water deprivation sheep seem to be well adapted to drought, as they are able to produce dry faeces and concentrated urine. In addition, their rumen can act as a buffer against dehydration. The effects of water deprivation seem to be largely dependent on ambient temperatures. For example, Knowles *et al.* (1993) found no evidence of dehydration during journeys of up to 24 h when ambient temperatures were not above 20°C. However, when ambient temperatures did rise above 20°C for a large part of the journey, there were clear indications that animals became dehydrated (Knowles *et al.*, 1994). Very many daytime journeys in the world are at higher temperatures than this.

If resting periods within the journey are considered as a means to prevent the effects of food and water deprivation several points have to be taken into account. First, short resting periods – of 1 h, for example – are insufficient and may even have detrimental effects on welfare. Hall *et al.* (1997) studied the feeding behaviour of sheep after 14 h of deprivation and concluded that few sheep obtained adequate food and water within the first hour. Knowles *et al.* (1993) found that recovery after long journeys took place over three phases and that after 24 h of lairage sheep seemed to have recovered from short-term stress and dehydration. It has been suggested that at least 8 h of lairage are needed to gain any real benefit (Knowles, 1998). A further problem is that sheep will not readily drink from unfamiliar water sources, even after prolonged periods of water deprivation (Knowles *et al.*, 1993). Therefore, it is likely that during short resting periods, sheep will not drink and the food they eat may lead to an increased water deficit, particularly if given concentrates (Hall *et al.*, 1997).

A second problem is that feeding during resting periods may cause competition between animals, and the stronger individuals may exclude the weaker ones (Hall *et al.*, 1997). It is therefore important that feeding and drinking space is enough for all animals to have access to food and water simultaneously. Recommended trough space for sheep is $0.112\,W^{0.33}$ m (Baxter, 1992). This means 30 cm for sheep of 20 kg body weight and about 34 cm for sheep of 30 kg body weight.

Finally, sheep can be reluctant to eat during lairage, particularly adult animals that are unfamiliar with the feed. Hay has been found to be the most widely accepted form of feed (Knowles, 1998), although Hall *et al.* (1997) found that only small amounts of hay were eaten by sheep after 14 h of food deprivation.

Journey duration and welfare

For all animals except those very accustomed to travelling, being loaded on to a vehicle is a particularly stressful part of the transport procedure. Furthermore, as journeys continue, the duration of the journey becomes more and more important in its effects on welfare. Animals travelling to slaughter are not given the space and comfort that a racehorse or showjumper are given. They are much more active, using much more energy, than an animal that is not transported. As a result they become more fatigued, more in need of water, more in need of food, more affected by any adverse conditions, more immunosuppressed, more susceptible to disease and sometimes more exposed to pathogens on a long journey than on a short journey.

In a survey of records of the transport of 19.3 million broilers killed in four processing plants in the UK, Warriss *et al.* (1990) found an average time, from loading to unloading, of 3.6 h, with a maximum of 12.8 h. Comparable average times for 1.3 million turkeys killed at two plants were 2.2 and 4.5 h, with maxima of 4.7 and 10.2 h (Warriss and Brown, 1996). Although there seem to be no published data, spent hens are thought to travel very long distances to slaughter in the UK because of the very small number of plants willing to process them. This long transport must be a cause of some considerable concern. Because poultry held in crates or drawers cannot be effectively fed and watered during transport, journeys must be considerably shorter than for red meat species. Mortality is increased progressively with longer transport times (Warriss *et al.*, 1992). These authors recorded the number of broilers dead on arrival in a sample of 3.2 million birds transported in 1113 journeys to a poultry processing plant. Journey times ranged up to 9 h with an overall average time of 3.3 h. Total time, from the start of loading birds on to the vehicle to the completion of unloading at the processing plant, ranged up to 10 h with an average of 4.2 h. The overall mortality for all journeys was 0.194%. However, as journey time increased, so did mortality rate. In journeys lasting less than 4 h the prevalence of dead birds was 0.16% while for longer journeys the incidence was 0.28%. In all journeys longer than 4 h mortality was therefore on average 80% higher than in all journeys shorter than this.

Birds that have previously suffered painful traumatic injuries such as broken bones and dislocations, which are not uncommon, will suffer progressively more in longer journeys. Animals may also become progressively more fatigued. Liver glycogen, which provides a ready source of metabolic fuel in the form of glucose, is very rapidly depleted after food withdrawal. Warriss *et al.* (1988) found depletion to negligible levels within 6 h. Broilers transported 6 h had only 43% the amount of glycogen in their livers compared with untransported birds (Warriss *et al.*, 1993).

Rest periods are impracticable and counterproductive for poultry since, as mentioned above, birds can neither realistically be offered food and water, nor can they be effectively inspected by veterinary authorities because of their close confinement in the transport receptacles. Moreover, with current systems of passively ventilated transport vehicles, the reduction in airflow, likely if vehicles stop without unloading the birds, is likely to lead to an increase in temperature within certain parts of the load and possibly cause the development of heat stress (hyperthermia) in the birds.

Horses stand during transport and have to make balance correction movements throughout any vehicle movement. In a study, comparing the effects of road transport ranging from <50 to 300 km, a range of physiological measures showed the extent to which the animals had to adapt. The levels of certain lymphocytes were increased in horses after journeys of 150–300 km. Plasma concentration of myocardial depressant factor (MDF) peptide fraction was significantly lowered by road transport in journeys exceeding 100 km. It has been reported that road transportation of Sanfratellani horses over distances of 130–200 km resulted in significant elevations in serum creatinine and creatinine kinase (CK). Similar changes were recorded after journeys of 130–350 km in 16 untrained horses of various breeds in aspartate amino transferase (AST), lactate dehydrogenase (LDH), alanine aminotransferase (AAT) and serum alkaline phosphatase (SAP) (Ferlazzo, 1995).

Disease incidence can increase on longer journeys and this has important implications for animal welfare and trade. For example, it is well known that an increased incidence of equine respiratory disease follows prolonged transport. Predisposition to respiratory disease after transport may be due to a marked increase in the numbers and, in viral-infected horses, the activity of pulmonary alveolar macrophages. Therefore, it is evident that transits of 8–12 h or more tend to be more measurably stressful and consideration should be given to monitoring welfare and pathology indicators.

A number of experiments have investigated the effects of journey length on cattle welfare. The majority of authors state that, with increasing duration of the transport, the negative effect on the animals increases as well, as represented through various physiological parameters such as body weight CK, NEFA, BHB, total protein, etc. A period of food and water deprivation of 14 h results in vigorous attempts to obtain food and water when the opportunity arises, although deprivation of 24 h is required before blood physiology changes in calcium, phosphorus, potassium, sodium, osmolarity and urea are apparent (Chupin *et al.*, 2000). However, food and water deprivation during a journey are likely to have much greater and more rapid effects. The extent of energy deficit when cattle were transported for two successive
[AU11] journeys of 29 h with a 24 h rest between them was quantified by Marahrens *et al.* (2003). After 14 h of transport, a break of 1 h for feeding and watering of the animals does not give ruminants enough time for sufficient food and water intake but just prolongs the total duration of the journey. Cattle become more fatigued as journeys continue and there are more frequent losses of balance.

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