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3 Causes of Poor Welfare and Welfare Assessment during Handling and Transport

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Introduction

The handling, loading, transporting and unloading of animals can have very substantial effects on their welfare. The welfare of an individual can be defined as its state with regard to its attempts to cope with its environment (Broom, 1986) and includes both the extent of failure to cope and the ease or difficulty in coping. Health is an important part of welfare, whilst 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, 2006).

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). If the effect of the environment is just stimulation, useful experience or an adrenal cortex response which has no adverse consequences, the individual is not stressed. Animal protection is a human activity which is directed towards the prevention of poor welfare in the animals. All stress involves poor welfare but there can be poor welfare without stress because there are no long-term consequences – for example, temporary pain or distress. All of these issues are discussed further in several papers in Broom (2001a).

In this chapter the factors which may result in stress during transport are first introduced. The methodology for assessment of the welfare of the animals during handling and transport is then explained. Finally, some of the various factors that affect the likelihood of stress are discussed, with examples from work on cattle and sheep.

Factors that may Result in Stress during Animal Handling and Transport

People are sometimes cruel to one another but generally believe that other people are aware and sentient 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. 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 whilst another person doing the same job may cause little or no stress. People may hit animals and cause substantial pain and injury because of selfish financial considerations, 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, all animals.

Laws can have a significant effect on the ways in which people manage animals. Within the European Union (EU), the Council Regulation (EC) No 1/2005 'On the protection of animals during transport and related operations' takes up some of the recommendations of two separate reports: (i) 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 (ii) 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 current discussion (2006).

Codes of practice can also have significant effects on animal welfare during transport. The most effective of these, sometimes just as effective as legislation, 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 others. This may be because of genetic differences associated with the breed of the animal or with selection for production characteristics. Differences between individuals with regard to coping ability also depend on housing conditions and with the extent and nature of contact with humans and conspecifics during rearing.

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. 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, grouping and distribution of animals on the vehicle. If there is withdrawal of food from those animals to be transported, this can affect 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 result in very poor welfare standards.

The behaviour of drivers towards animals whilst loading and unloading and the way in which people drive vehicles are affected by the method of payment. If personnel are paid more for loading or driving quickly welfare standards will be worse, so such methods of payment should not be permitted. Payment of handling and transport staff at a higher rate for ensuring that 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 of 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 and the risks of disease transmission. Disease is a major cause of poor welfare in transported animals. 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 contact numbers for obtaining 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 major effect on animal welfare. The quality of driving can result in poor levels of welfare because of the animals' difficulty in maintaining balance, motion sickness, injury, etc. The ambient 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 situations inevitably lead to problems. Hence, good monitoring of the animals with inspections of adequate frequency – and in conditions that allow thorough inspection – are important.

Assessment of Welfare

A variety of welfare indicators that can be used to assess the welfare of animals being handled or transported are listed below. Some of these assessments are of short-term effects whilst others are more relevant to prolonged problems. With regard to animals being transported to slaughter, it is mainly the assessment of short-term effects such as behavioural aversion or increased heart rate that is used, but some animals are kept for a long period after transport and assessments such as increased disease incidence or suppression of normal development give information about the effects of the journey on welfare.

Assessments of welfare standards may incorporate the following (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 at coping
- Immunosuppression
- Disease prevalence
- Behavioural attempts at coping
- Behaviour pathology
- Brain changes, e.g. those indicating self-narcotization
- Body damage prevalence
- Reduced ability to grow or breed
- Reduced life expectancy.

Details of these and other measures may be found in Broom (1998), Fraser and Broom (1997) and Broom and Johnson (2000).

Behavioural assessment

Changes in behaviour are obvious indicators that an animal is having difficulty coping with handling or transport, and 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).

Behavioural responses are often demonstrated during painful or otherwise unpleasant situations. Their nature and extent vary from one species to another according to the selection pressures that have acted during the evolution of the mechanisms controlling behaviour. Human approach and contact may elicit *anti-predator behaviour* in farm animals. However, with experience of handling, these responses can be greatly reduced in cattle (Le Neindre *et al*., 1996).

Social species that 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 which 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 that were most aggressive in their home pen were also more likely to fight during pre-transport or pre-slaughter handling, but pigs 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 a test that reveals whether or not 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 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 humans during the procedure can show extreme responses. However, in most efficient loading procedures, sheep are not greatly affected and cattle are only sometimes affected. Broom *et al*. (1996) and Parrott *et al*. (1998b) showed that sheep show largely physiological responses and these are associated with the novel situation encountered in the vehicle rather than with the loading procedure.

Once a journey starts, 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 animals will lie down if the opportunity arises. Unfortunately for the animals, many journeys involve so many lateral movements or sudden brakings or accelerations that they cannot lie down.

One important behavioural measure of welfare when animals are transported is the amount of fighting which they show. 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.

One further, valuable, method of using behavioural studies in the assessment of farm animal welfare during handling and transport involves using the fact that the animals remember aversive situations in experimentally repeated exposures to such situations. Any stockkeeper will be familiar with the animal that 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 has previously occurred once.

These observations give us information about both the past and present welfare of the animal. If the animal tries not to return to a place where it previously 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 that had been driven down a race to a point where gentle handling occurred traversed the race as rapidly or more rapidly on a subsequent day. Sheep that had been 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 both 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 these indicate stress. Other behavioural measures provide evidence of good or poor welfare but not necessarily of stress.

Physiological assessment

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 below. Some physiological assessment criteria are detailed in Table 3.1.

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, tending to be higher before than after midday. 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. With regard to major effects where the response reaches the maximal possible level – for example, cortisol in plasma during 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 that is important here rather than a

Table 3.1. 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, ↑ β-OHB, ↓ glucose, ↑ urea
Dehydration	↑ Osmolality, ↑ total protein,↑ albumin, ↑ PCV
Physical exertion	↑ CK, ↑ lactate
Fear, lack of control	↑ Cortisol, ↑ PCV
Motion sickness	↑ Vasopressin
Measured otherwise	
Fear, physical effects	↑ Heart rate, ↑ heart rate variability, ↑ respiration rate
Hypo-/hyperthermia	Body temperature, skin temperature

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

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.

Some of the parameters useful in the assessment of stress will now be described.

Heart rate

Heart rate can decrease when animals are frightened but, in most farm animal studies, tachycardia – increased 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 by animals during handling, loading on to vehicles and certain acute effects during the transport procedure itself. However, some adverse conditions may lead to an elevated heart rate for quite long periods. Parrott *et al*. (1998a) showed that heart rate increased from about 100 to about 160 beats/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).

Respiratory rate

Observation of animals can provide information about physiological processes 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 that is disturbed by events in its environment may suddenly start to breathe more rapidly.

Other directly observable responses

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.

Hormones and metabolites

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

ADRENAL CORTICAL HORMONES. Adrenal cortical changes occur in most of the situations which lead to aversion behaviour or increased heart rate, but the effects take a few minutes to become evident and last for 15–120 min, or a little longer. An example comes from work on calves (Kent and Ewbank, 1986; 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.

Salivary cortisol measurement is useful in cattle. In the plasma, most cortisol is bound to protein but it is the free cortisol that 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 that 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 in some other species.

The injection of pilocarpine and sucking of citric acid crystals, which stimulate salivation, have no effect on the salivary cortisol concentration. However, any rise in salivary cortisol levels following some stimuli is delayed by a few minutes as compared with the comparable rise in plasma cortisol concentration.

Animals demonstrating substantial adrenal cortical responses during handling and transport also show increased body temperature (Trunkfield *et al*., 1991). This increase is usually of the order of about 1°C, but the actual level at the end of the journey will depend upon the extent to which any adaptation of the initial response has occurred. Body temperature can be recorded in transit by implanted or superficially attached monitors linked directly or telemetrically to a data storage system.

Parrott *et al*. (1999) deescribed deep body temperature in eight sheep. When the animals were loaded on to a vehicle and transported for 2.5 h body temperature increased by about 1°C, and in males was 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 after exercise. It would seem that prolonged increases in body temperature are an indicator of poor standards of welfare.

PITUITARY HORMONES. The measurement of oxytocin has not been of particular value in animal transport studies (e.g. Hall *et al*., 1996). However, plasma β-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 different 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.

Metabolites

Creatine kinase is released into the blood when there has been muscle damage, e.g. bruising, or vigorous exercise. It is clear that some kinds of damage affecting welfare result in creatine kinase release, so this 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 that 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 will have been unable to drink for much longer than the normal interval. 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.

Plasma studies in chickens reared for meat production deprived of food for 10 h prior to 3 h of transport, when compared with those in non-deprived birds, showed higher thyroxine and lower tri-iodothyronine, triglyceride, glucose and lactate concentrations, indicating negative energy balance and poor welfare (Nijdam *et al*., 2005).

Another measure that gives information about the significance for the animal of food deprivation is the time interval since the previous 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.

Haematocyte parameters

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

Increased adrenal cortical activity can lead to immunosuppression. One or two studies in which transport affected T-cell function were 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.

Measurements of the ratios of various white blood cells – for example the heterophil:lymphocyte ratio – are affected by a variety of factors, but some kinds of restraint seem to affect the ratio consistently and so can provide 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 efficiently because of handling/transport treatment, the animal is coping less well with its environment and the welfare standards are poorer than in an animal that is not immunosuppressed.

Examples of the immunosuppressive effect of transport are: (i) the reduction in four different lymphocyte subpopulations after 24 h of transport in horses (Stull *et al*., 2004); and (ii) the reduction in phytohaemagglutinin-stimulated lymphocyte proliferation in *Bos indicus* steers during the 6 d 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, whilst others are not measures of stress because the effect will be brief or slight.

Carcass and mortality assessment

Measures of body damage, of a major disease condition or of increased mortality are indicators of long-term adverse effects – and hence stress. However, a slight bruise or cut will result in some degree of poor welfare but not necessarily stress, as the effect may be very brief. Death during handling and transport is usually preceded by a period of poor welfare. Mortality *records* during journeys are often the only records giving information about welfare during the journey, and the severity of the problems for the animals are often only too clear from such records.

Amongst extreme injuries during transport are broken bones. These are rare in the larger animals, but poor loading or unloading facilities and cruel or poorly trained staff who are attempting to move the animals may cause severe injuries. It is the laying hen, however, which is most likely to have bones broken during transit from housing conditions to point of slaughter (Gregory and Wilkins, 1989), especially if the birds have previously had insufficient exercise in a battery cage (Knowles and Broom, 1990).

Bruising, scratches and other superficial blemishes can be scored in a precise way and, when carcasses are downgraded for these reasons, those in charge of the animals can reasonably be criticized for not making sufficient efforts to prevent poor welfare. There is a cost of such blemishes to the industry, as well as to the animals. This cost, in monetary and animal welfare terms, of dark firm dry (DFD) and pale soft exudative (PSE) meat is huge.

DFD meat is associated with fighting in cattle and pigs, but it may also be evidenced in cattle that have been threatened but not directly involved in fighting (Tarrant, personal communication). PSE meat is in part a consequence of possession of certain genes and occurs more in some strains of pigs than in others, but its occurrence is related in most cases to other indicators of poor welfare (Tarrant, personal communication).

Poultry meat quality can often be adversely affected for similar reasons. In a large-scale study of chickens reared for meat production and transported to slaughter in the Netherlands and Germany, Nijdam *et al*. (2004) found that the mean mortality was 4.6 and the number with bruises was 22 per thousand birds. The major factors that had increased the mortality rate were: (i) increased stocking density in transport containers; (ii) increased transport time; and (iii) increased time in lairage before slaughter.

When animals are subjected to violent handling and respond by energetic strugglling, a possible consequence is capture myopathy. This muscle damage that occurs will impair muscular action in the future, at least in the short term, and is an indicator of poor welfare because it reduces coping ability and may be associated with pain (Ebedes *et al*., 2002).

Experimental methods of assessment

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

- 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).
- 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; Becker *et al*., 1989; Dalin *et al*., 1993; Knowles *et al*., 1994).
- Uncontrolled studies during long or short commercial or experimental journeys (Lambooij, 1988; Hall 1995).
- Studies comparing animals that were transported with animals that had been left behind to act as controls (Nyberg *et al*., 1988; Knowles *et al*., 1995).
- 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 whilst 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*. (1998a, b) 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 maximization of 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 of Caesarean section. Some of these effects may affect welfare during handling and transport.

Certain rapidly growing beef cattle have joint disorders that 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 that of the dairy cattle of 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 during transporting, or the rearing conditions must be changed. An extreme example of such an effect is osteopenia and vulnerability to broken bones, which is twice as high in battery hens than in hens that 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 of 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 DFD 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 by 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.

Handling, loading, unloading and welfare

Well-trained and experienced stockpeople know that cattle can be readily moved from place to place by human movements that take advantage of the animal's flight zone (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 animal intends to go.

Handling animals without the use of sticks or electric goads results in better welfare and less risk of poor carcass quality. Sound knowledge of animal behaviour and good facilities are important for animal welfare during handling and loading.

Ambient temperature and other physical conditions during transport

Extremes of temperature can cause very poor welfare standards 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.

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 far less able to deal with sudden movements 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 to 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 plasma cortisol concentrations were substantially higher on winding than on straight roads. Tarrant *et al*. (1992) studied cattle at a rather high, at an average and at a low commercial stocking density and found that falls, bruising, cortisol and creatine kinase levels all increased with stocking density. Careful driving and a moderate stocking density are crucial for good standards of welfare.

Disease, welfare and transport

The transport of animals can lead to increased disease – and hence to poorer welfare – in a variety of ways: (i) tissue damage and malfunction; (ii) pathological effects which would not otherwise have occurred resulting from pathogens already present; (iii) disease from pathogens transmitted from one transported animal to another; and (iv) disease in non-transported animals because of pathogen transmission from transported animals. Exposure to pathogens does not necessarily result in infection or disease in an animal. Factors influencing this process include the virulence and the dose of pathogens transmitted, route of infection and the immune status of the animals exposed (Quinn *et al*., 2002).

Enhanced susceptibility to infection and disease as a result of transport has been the subject of much research (Broom and Kirkden, 2004; Broom, 2006). Many reports describing the relationship between transport and incidence of specific diseases have been published. As an example, ‘shipping fever’ is a term commonly used for a specific transport-related disease condition in cattle. It develops between a few hours and 1–2 d following transport.

Several pathogens can be involved, such as *Pasteurella* species, bovine respiratory syncytial virus, infectious bovine rhinotracheitis virus and several other herpes viruses, para-influenza 3 virus and a variety of pathogens associated with gastrointestinal diseases, such as rotaviruses, *Escherichia coli* and *Salmonella* spp. (Quinn *et al*., 2002). Transport in general has been shown to result in increased mortality in calves and sheep (Brogden *et al*., 1998; Radostits *et al*., 2000), salmonellosis in sheep (Higgs *et al*., 1993) and horses (Owen *et al*., 1983). In calves, it can cause pneumonia and subsequent mortality associated with bovine herpes virus–1 (Filion *et al*., 1984), as a result of a stress-related reactivation of herpes virus in latently infected animals (Thiry *et al*., 1987).

In some cases, particular aspects of the transport situation can be linked to disease. For example, fighting caused by the mixing of different groups of pigs can depress anti-viral immunity in these animals (de Groot *et al*., 2001). The presence of viral infection increases the susceptibility to secondary bacterial infection (Brogden *et al*., 1998).

Transmission of a pathogenic agent begins with shedding from the infected host through oronasal fluids, respiratory aerosols, faeces or other secretions or excretions. The routes of shedding vary between infectious agents. Stress related to transport can increase the amount and duration of pathogen shedding and thereby result in increased infectiousness. This is described for *Salmonella* in various animal species (Wierup, 1994).

The shedding of pathogens by the transported animals results in contamination of vehicles and other transport-related equipment and areas, e.g. in collecting stations and markets. This may result in indirect and secondary transmission. The more resistant an agent is to adverse environmental conditions, the greater the risk that it will be transmitted by indirect mechanisms.

Many infectious diseases may be spread as a result of animal transport. Outbreaks of classical swine fever in the Netherlands and of foot and mouth disease in the UK were much worse than they might have been because animals had been transported and, in some cases, had transmitted the disease at staging points or markets.

Schlüter and Kramer (2001) summarized the outbreaks in the EU of foot and mouth disease and classical swine fever and found that, once this latter disease was in the farm stock, 9% of further spread occurred as a result of transport. In a recent epidemic of Highly Pathogenic Avian Influenza virus in Italy it was found that the movement of birds by contaminated vehicles and equipment created a significant problem in the control of this epizootic.

Major disease outbreaks constitute very important animal welfare as well as economic problems, and regulations concerning the risks of disease are necessary on animal welfare grounds. If stress and the mixing of animals and their products are minimised, disease – and hence poor welfare standards – can be prevented or rendered less likely.

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