THE IMPORTANCE OF ANIMAL COMFORT FOR ANIMAL PRODUCTION IN INTENSIVE GRASSLAND SYSTEMS

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Abstract

Animals utilise a wide range of regulatory systems to control the conditions within their bodies or homeostasis. These regulatory systems control for example, body temperature, nutritional state, water balance, social interactions and fear and these systems react to environmental and endogenous stimuli so as to correct or prevent displacements from the optimal range. The behavioural and physiological responses utilised by the animal are usually proportional to the challenge to homeostasis. The stress response commences with the central nervous system perceiving a potential challenge to homeostasis. Once the central nervous system perceives a threat, it develops a biological response or defence that consists of some combination of the four general biological defence responses: behavioural responses, responses of the autonomic nervous system, responses of the neuroendocrine system and responses of the immune system. Although biological regulation is occurring constantly, adaptation is not always possible and when homeostasis fails, there are biological costs for the animal, which may include growth and reproductive failure, injury, disease as a consequence of immunosuppression or even death. While animal comfort is not strictly defined in the scientific literature, an appropriate definition of comfort that is utilised in this review is a dictionary definition, "at ease in body and mind".

With the likely trend to greater intensification of grassland production, there are a number of factors that will affect animal comfort. Both group size and space allowance are key features of the social environment that may affect animal comfort, while the nature of human contact is an important factor, which through fear, may also affect animal comfort. Thermal stressors can have significant impact on animal comfort with cold around parturition being a serious problem for the offspring and heat having adverse consequences for adult animal production and welfare. The concerns for animal comfort over husbandry procedures include practices ranging from simple interventions such as shearing that involve challenges including restraint, close human contact and isolation to more complex surgical interventions such as tail docking and castration that may include additional challenges such as acute and chronic pain, as well as short-term production depressions. Others issues include risks associated with animal biotechnologies, including simple manipulations such as twinning to more complex transgenic manipulations.

Introduction

The relative constancy of conditions that exist within the body of a healthy animal is achieved by the operation of innumerable homeostatic controls (Broom and Johnson, 1993). Animals utilise a wide range of biological systems, behavioural and physiological, to both regulate their lives and deal with difficulties. These homeostatic control systems are activated once a physiological displacement arises and thus react to environmental and endogenous stimuli so as to correct or prevent displacements from the optimal range. The response is usually proportional to the actual or expected change (Broom and Johnson, 1993).

Traditionally homeostasis has been used to denote the equilibrium of the internal environment of an individual animal with respect to its physiological requirements such as body temperature, blood sugar concentrations, oxygen levels, etc. However, it can also be applied to any type of biological regulation such as that of a population (McFarland, 1981). Thus there is now less distinction between homeostatic aspects of behaviour, such as feeding, drinking and temperature regulation, and non-homeostatic aspects of behaviour such as aggression, fear and sexual behaviour (McFarland, 1985). For example, the control of sexual behaviour is not fundamentally different from that of feeding or drinking.

Although biological regulation is occurring constantly, adaptation is not always possible and when homeostasis fails, there are biological costs for the animal, which may include growth and reproductive failure, injury, disease or even death (Cannon, 1914, Selye, 1976). Death is the ultimate consequence of failure to adapt, however it should be appreciated that less severe challenges to homeostasis, through activation of behavioural and physiological responses, can result in less serious biological costs such as impaired growth and reproduction. Difficult or inadequate adaptation also generates animal welfare problems.

While animal comfort is not strictly defined in the scientific literature, an appropriate definition of comfort that will be used in this presentation is “at ease in body and mind” (The Concise Oxford Dictionary, 1973). In reviewing the importance of animal comfort on animal production, this paper will consider animal discomfort as synonymous with “a challenge to homeostasis”. In examining some of the factors that may affect animal comfort, this paper will also consider their implications on animal productivity and welfare.

While it is difficult to predict future changes in livestock production, the need to produce cheap and safe animal products as the world’s population increases is likely to result in greater intensification of livestock production. This pressure for intensification of production will extend beyond the main farm animal species that presently supply food and fibre for humans such as cattle, sheep and goats, to other ruminants such as buffalo, camel, deer, llama, reindeer and yak. With the intensification of grassland systems for livestock, there are a number of factors that will affect animal comfort such as the social environment, human interactions, climatic conditions, conventional husbandry procedures and new biotechnological manipulations. This review is not intended to provide an extensive list of the factors that may affect animal comfort in species farmed in intensive grassland systems. Such a task is difficult with our current knowledge and the large numbers of both species and the likely variations in these production systems in the future. This review will identify some of the main factors that may be influential on the basis of research that has demonstrated effects either in some species in intensive grassland systems or in other production systems such as intensive indoor systems. Since intensive grassland systems are likely to continue to develop in the future, it is important that factors that are likely to be problematic are evaluated and addressed because of the implications of animal comfort on animal productivity and welfare.

Challenges to homeostasis and their consequences

The vitality of all animals depends ultimately on the efficient operation of the regulatory systems that control the conditions within their bodies or homeostasis (Broom and Johnson, 1993). These regulatory systems control for example, body temperature, nutritional state, water balance, social interactions and fear and these regulatory systems react to environmental and endogenous stimuli so as to correct or prevent displacements from the optimal range. The behavioural and physiological responses utilised by the animal are usually proportional to the challenge to homeostasis. The implications for both animal productivity and welfare when homeostasis is challenged are best illustrated by recognising both the adaptive responses that animals may utilise in attempting to cope and their consequent biological costs.

The stress response commences with the central nervous system perceiving a potential challenge (stressor) to homeostasis. Once the central nervous system perceives a threat, it develops a biological response or defence that consists of some combination of the four general biological defence responses: behavioural responses, responses of the autonomic nervous system, responses of the neuroendocrine system and responses of the immune system (Moberg, 2000). The central nervous system integrates these responses to provide the animal with the principal resources to cope with the stressor. For example when a rat is attempting to maintain its body temperature in a cold environment, it may respond behaviourally by seeking shelter or building a nest and physiologically by reducing peripheral blood flow and increasing metabolism. The type and combination of the behavioural and physiological responses are dependent on the characteristics of the stressor such as its magnitude and duration.

It is obvious that for many stressors, the first and, at times, the most biologically economical and effective response is a behavioural one. If the challenge for example is the close presence of a dominant group-mate or a potential predator, either freezing or avoidance following startle and orientation responses may be very effective strategies to deal with the threat. Alternatively, defensive responses such as growling and a threatening stance or even attack may be appropriate. However, behavioural responses may not be appropriate or effective for all situations, particularly when the behavioural options are limited or thwarted (Moberg, 2000). Nevertheless, some component of behaviour is likely to be involved in every stress response.

In concert with the behavioural responses, the physiological responses that can be utilised by the animal are elicited basically in three series of events, with the full elicitation of these dependent on the time of exposure to the stressor and the success of the biological responses in coping with the challenge (Hemsworth and Coleman, 1998). The first series of physiological events is characterized by a rapid, specific response by the autonomic nervous system and consequent secretions of catecholamines (adrenaline [epinephrine] released from the adrenal medulla and noradrenaline [norepinephrine] released from the adrenal medulla and the nerve endings of the sympathetic nervous system). This immediate or “emergency” response is the ‘fight or flight’ response proposed by Walter Cannon (Cannon, 1914) and is the principal regulatory mechanism that allows the animal to meet physical or emotional challenges by its effects on metabolic rate, cardiac function, blood pressure, peripheral circulation, respiration, visual acuity and energy availability and use. A particularly important biological effect is the adrenaline-dependent production of glucose from liver glycogen (glycogenolysis) for an immediate energy supply. This initial reaction lasts for only a short period of time and, if the stressor is not removed, a second series of events occurs.

The second series, called the acute stress response, is part of Hans Selye’s ‘general adaptation syndrome’ (Selye, 1946; 1976) and is a corticosteroid-dependent mechanism. Corticotrophin-releasing factor (CRH) released from the hypothalamus stimulates adrenocorticotrophic hormone (ACTH) release from the pituitary, which, in turn, stimulates the release of corticosteroids or glucocorticoids from the adrenal cortex. Arginine vasopressin (AVP) from the hypothalamus has a role in some species in stimulating ACTH secretion (Matteri et al., 2000). This acute response may last from minutes to hours and has the major function of providing glucose from food or muscle protein (gluconeogenesis) for the required increased metabolic performance. Therefore, during this stage a steady state is achieved in which the increased demand for energy is met by increased metabolic performance. This physiological state of stress disappears on removal of the stressor with generally no ill effects other than a depletion of energy reserves. This is an effective mechanism whereby the animal can adapt to changes in its environment.

While acute stressors are short acting, there are situations in which they could have detrimental effects on the animal. For example, while a single event of an acute stress response may not be detrimental, it is unknown what magnitude and duration an acute stress response or a series of acute stress responses would need to be before there was adverse effects. There is a number of examples where an acute stress response at specific times in the reproductive cycle has interfered with different aspects of reproduction (Moberg, 1985; Rivier and Rivest, 1991; Clarke *et al*., 1992). Because of the importance of the series of carefully orchestrated endocrine events required for oestrus, ovulation and conception and the known effects of stress on these endocrine events, it is perhaps not surprising that activation of the hypothalamic-pituitary-adrenal (HPA) axis prior to mating may adversely affect female reproduction.

If the stressor continues, the response proceeds to the third series of events, which is the chronic stress response. Again, this series of events is a corticosteroid-dependent mechanism, but while in the acute phase the effects are potentially beneficial, this chronic activation of the HPA axis comes at a physiological cost to the animal such as a decreased metabolic efficiency, impaired immunity and reduced reproductive performance. It is well known that the long-term activation of the HPA axis can have marked effects on efficiency of growth with for example the catabolic effects of ACTH and corticosteroids (Elsasser et al., 2000). Corticosteroids also support the synthesis and action of adrenaline in stimulating gluconeogenesis and lipolysis (Matteri et al., 2000). Stress-induced changes in the secretion of pituitary hormones have been implicated in failed reproduction (Clarke *et al*., 1992; Moberg, 2000) and immune competency (Blecha, 2000). How serious these costs are, depends on how long the animal is required to divert physiological resources to maintain homeostasis. While the role and actions of corticosteroids in acute and chronic stress responses are well known, this is not to imply that the HPA axis is the only neuroendocrine axis affected by stressors. The secretion of prolactin and somatotrophin (growth hormone) are equally sensitive to stress and thyroid-stimulating hormone and the gonadotrophins (luteinizing hormone and follicle-stimulating hormone) are either directly or indirectly modulated by stress (Moberg, 2000).

It is becoming increasingly obvious that the immune system in its own right is one of the major defence systems responding to a stressor. The increased incidence of disease in animals suffering from stress has long been recognised as a consequence of modulation of the immune system principally by the HPA axis. However the central nervous system has a direct role on regulation of the immune system (Moberg, 2000). Furthermore, while the adrenal, somatotrophic and thyroid axes have a critical role in shaping metabolism under the influence of stress, it is also clear that endocrine-immune interactions are also important (Elsasser et al., 2000).

As previously mentioned, while some component of behaviour is likely to be involved in every stress response, behavioural responses may not be appropriate or effective for all situations. Indeed, long-term behavioural responses, as with long-term neuroendrocrine responses, may indicate difficult or inadequate adaptation. For example, a lack of resource such as a nutrient requirement or a situation in which the animal is highly motivated but is unable to perform an appropriate behavioural response may lead to either redirected behaviour or stereotypies (Broom and Johnson, 1993). These responses often include movements associated with finding or obtaining the resource. Stereotypies may also develop as a consequence of either a lack of stimulation or overstimulation (Broom and Johnson, 1993), but it should be recognised that there has and continues to be considerable controversy on the causation and function of stereotypies in farm animals. Indeed, some evidence exists to indicate that some stereotypies may be coping mechanisms in the short term, but it is unknown whether they exert benefits in the long term (Hemsworth and Coleman, 1998). Nevertheless, irrespective of the function of stereotypies, the existence of a stereotypy is at the least indicative of a past problem for the animal in coping with its conditions.

Thus the hormones secreted from the hypothalamic-pituitary system have a broad, long-lasting effect on the body and thus challenges to homeostasis that result in such neuroendorine responses clearly have implication for animal productivity. In contrast, the implications of a challenge to homeostasis on animal welfare are less obvious. Behavioural responses certainly may lead to injuries sustained in trying to avoid the stressor. Stereotypies that result in physical damage or illness to the animal (e.g., the development of lesions in stall-housed sows that persistently rub their tail roots from side to side against stall fittings (Ewbank, 1978) or wind-sucking in horses where persistent wind-sucking can lead to gastrointestinal catarrh and colic (Fraser and Broom, 1990)) have obvious and immediate implications for the welfare of the animals. Behavioural change in which there is abnormality either in the pattern, frequency or context of the behaviour from that which is generally expected, and results in adverse effects on the morbidity or mortality of the individual or others clearly has welfare implications. For example, tail biting in pigs, for which the cause(s) is poorly understood, results in restlessness, poor growth, and possible paralysis and mortality due to infections in the recipients (van Putten, 1969). Similarly chewing of wood, soil, hair or faeces, through the ingestion of this material, has serious welfare implications for the animal. Extreme environmental conditions and stressful management practices have been shown to influence the health of domestic animals through disturbances of the HPA axis (Blecha, 2000). There is also the ethical issue of permitting animals to experience a prolonged stress response: the livestock industries have a moral obligation to humanely manage their livestock and thus while acute stress is a normal occurrence for animals in both wild and domestic conditions, the incidence of acute stress of high magnitude and duration should be minimised and chronic stress should not be tolerated.

Factors affecting animal comfort

Social environment

Social stress is particularly effective in producing chronic changes in the function of the HPA axis (Mendoza et al., 2000). An important behavioural trait that influenced the domestication of ungulate and galliform species was their social organization: these species had the ability to live in relatively large groups without marked year-round territoriality (Stricklin and Mench, 1987). This trait has been further emphasized through artificial selection during domestication, but nevertheless social instability is an important social stressor for livestock. Social separation is another important social stressor, however separation from group-mates in most production systems generally only occurs for short periods such as during husbandry procedures.

It is particularly important to understand the effects of group size and space allowance on the productivity and welfare of livestock in intensive grasslands systems. In addition to aggression caused by competition over resources and meetings between unacquainted animals, some aggression in farm animals may function to maintain distance between individual animals (Fraser and Rushen, 1987). Indeed high levels of aggression may reflect high stocking densities. While increases in group size and reductions in space available may have different effects, the scientific literature on farm animals generally indicates that both increases in group size and decreases in space are associated with increased aggression (Fraser and Rushen, 1987).

While the effects of varying the size of small groups have been studied, neither maximal nor optimal group sizes have been identified for most livestock (Stricklin and Mench, 1987). Conventional thinking has been that small groups form stable social hierarchies and that as group size increases and individual animal recognition declines, aggression will increase. This has lead to the widespread view in the literature that if animals regularly encounter unfamiliar animals in large groups in confined areas, aggression will increase with adverse effects on production and welfare. For instance, a commonly quoted estimate of the total number of group members that can be recognised or remembered by each individual is 50 to 70 in cattle (Fraser and Broom, 1990). Under free-ranging farming systems voluntary grouping is evident (Wagnon et al., 1966), but this may not be possible with intensive production systems. However, there is recent evidence in laying hens and broiler chickens (Pagel and Dawkins, 1997; Estevez et al., 1998; Nicol et al., 1999) that aggression declines as group size substantially increases with space allowance remaining constant. Thus the greater resources in very large groups such as total and free space and availability of preferred lying areas, may reduce the need to form dominance hierarchies that function to control aggression in situations of limited resources. Pagel and Dawkins (1997) have also argued that if animals are able to adjust their behaviour according to the size of the group, they may abandon all attempts to establish dominance hierarchies. Hughes et al. (1997) also suggested that animals might be more socially tolerant in large groups. Clearly the role of individual animal recognition and social hierarchies in reducing aggression in very large groups requires investigation because of the implications on animal comfort.

Considerable research has been conducted on the effects of space on growth and reproductive performance of animals intensively housed (see Albright and Arave, 1997; Chapple, 1993; Hughes and Hemsworth, 1994). While not specifically studied, presumably the adverse effects of space on growth and reproductive performance are a consequence of aggression and, in turn, injury and stress limiting growth and reproductive efficiency in sub-optimal social environments. In contrast to livestock that are intensively housed, few studies have been conducted on the effects of space on livestock in intensive grasslands systems. The minimum space requirements for optimum performance of animals in intensive outdoor systems is difficult to define because of interactions with such factors as animal size, feed supply and weather. For instance, the variation in the literature in the recommended minimum space requirements for feedlot cattle for optimum growth performance (eg 9 to 20 m^2/animal, Fell, 1994) presumably reflects the influence of these interacting factors.

Aggression is likely to increase in situations of high stocking density when there is competition for limited resources such as feed or preferred lying space (Fraser and Rushen, 1987). There are also some specific production stages in which confinement may become increasingly influential. For example, close confinement and highly synchronized parturition in cattle may lead to mismothering, desertion and reduced colostrum intake in neonates (Edwards, 1982). Introducing unfamiliar animals, particularly into large high-density groups, invariably leads to aggression and Stricklin and Mench (1987) have discussed some of the associated production losses such as buller syndrome in feedlot cattle, dark cutting carcasses and possibly shipping fever in calves.

Therefore with developments in the intensification of grassland systems, there is a clear need to understand the effects of stocking density (group size and space) on aggression particularly in situations where there may be competition for resources such as feed, water and lying spaces. In addition to welfare concerns, prolonged unresolved aggression, because of the risks of chronic stress and injury, may have substantial detrimental effects on growth, reproduction and health.

Human interactions

Human-animal interactions are a common feature of modern intensive farming systems and these interactions may have marked consequences on animal productivity and welfare. Research, particularly in the dairy, pig and poultry industries, has shown that the interactions between stockpeople and their animals can limit the productivity and welfare of livestock (Hemsworth and Coleman, 1998) and it is useful to review some of this research to highlight the implications of human-animal interactions on livestock in intensive grassland systems.

Many of the interactions used by stockpeople are routinely and, at times, habitually used when handling livestock. While many of these interactions may appear harmless to the animals, this research has shown that the frequent use of some of these routine behaviours by stockpeople can result in farm animals becoming highly fearful of humans. It is these high fear levels, through either acute or chronic stress, that appear to limit ease of handling, productivity and welfare of farm animals (Hemsworth and Coleman, 1998).

Using either the animal's approach behaviour to a stationary experimenter or the animal's avoidance behaviour to an approaching experimenter to assess the animal's fear of humans, a series of studies in the dairy, pig and poultry industries has shown negative correlations between fear of humans and productivity (Hemsworth *et al*., 1981b, 1989, 1994a, 2000; Barnett *et al.*, 1992; Breuer *et al*., 2000). These negative correlations, based on farm averages, indicate that high levels of fear of humans may be an important factor limiting the productivity of livestock that are intensively handled. The results of this research in commercial situations have generally been supported by the results of handling studies on livestock. Studies on pigs indicate that high fear of humans, through a chronic stress response, can limit the growth and reproduction of pigs (for example, Gonyou *et al.*, 1986; Hemsworth *et al.*, 1981a, 1986a, 1987, 1996a; Hemsworth and Barnett, 1991). Handling studies on poultry have shown that chickens and laying hens are particularly sensitive to visual contact with humans (Jones, 1993; Barnett *et al.,* 1994) and that handling treatments, presumably increasing fear of humans, may depress growth (for example, Gross and Siegel, 1979, 1980, 1982; Collins and Siegel, 1987). Handling also affects the behavioural response of cattle to humans (Boissy and Bouisou, 1988; Boivin *et al*., 1992; Breuer *et al*., 1997) and recent studies have shown that aversive handling may elevate both catecholamine and cortisol concentrations and depress the milk yield of dairy cows (Breuer *et al.*, 1997; Breuer, 2000; Rushen *et al*., 1999). Dairy cows are also at risk of becoming lame if they are forced to move quickly (Chesterton et al., 1989).

Significant sequential relationships have also been found in the dairy and pig industries between the stockperson's attitudes and behaviour towards animals and the behavioural response of farm animals to humans (Hemsworth *et al.*, 1989, 2000; Coleman *et al.*, 1998; Breuer *et al*., 2000). The stockperson's beliefs about his or her behaviour and the behaviour of their animals were predictive of the stockperson's behaviour towards animals, which in turn was predictive of the level of fear of humans at the farm. The existence of these sequential relationships indicates the possibility of improving animal behaviour, productivity and welfare by improving the attitudes and behaviour of stockpeople. Indeed, studies in both the dairy and pig industries have shown that it is possible to firstly, improve the attitudinal and behavioural profiles of stockpeople towards livestock and secondly, reduce level of fear and improve productivity of the dairy cows and pigs (Coleman *et al*., 2000; Hemsworth *et al*., 1994a; 1999).

In addition to effects on animal productivity and welfare, fear of humans may also affect ease of handling. For instance, limited research with pigs has shown that animals that are fearful of humans are generally the most difficult to handle (Gonyou *et al*., 1986; Grandin *et al*., 1987; Hemsworth et al., 1994b). Animals are generally wary of entering an unfamiliar location and if they are fearful of both the new environment and the handler, they are likely to show exaggerated responses to handling: fearful animals may baulk or flee back past the handler, thus requiring more effort and time on the part of the handler to move them. Handling by reducing fear of humans has also been shown to affect ease of handling in other livestock. Studies on cattle, sheep and horses have shown that handling, generally involving speaking and touching the animals particularly during infancy, improved their subsequent ease of handling (for example, Boissy and Bouisou, 1988; Boivin *et al*., 1992, Hargreaves and Hutson, 1990; Hemsworth *et al*., 1996b; Lyons, 1989; Mateo *et al*., 1991; Waring, 1983).

Intensive grassland production involves several levels of interaction between stockpeople and their animals. Many interactions are associated with regular observation of the animals and their conditions and thus this type of interaction often involves only visual contact between the stockperson and the animals. Visual and auditory interactions may also be used to move animals, and in some situations tactile interactions may be used. All interactions contribute to the overall relationship that animals have with humans. Because of the potential for negative interactions by the stockperson, some authors have questioned the necessity of interactions between humans and livestock and Hemsworth and Coleman (1998) have reviewed this topic.

An essential role of stockpeople in achieving high animal performance and welfare is the careful observation of animals under their care. Although animal conditions such as ambient temperature, quality and quantity of feed and presence of water can be remotely monitored, direct observation of animals often provides the first evidence of departure from normality in animals. In particular, behavioural change can be utilised by stockpeople to identify abnormality, such as illness or stress. For example, an animal not feeding, a social animal voluntarily separated from the group or an animal unresponsive to environmental change such as the approach of the stockperson, can be used to identify the early stages of a problem and enable a prompt response to the problem. Often the diagnosis of the problem by veterinarians relies on reports from the stockperson on the behaviour of the animal. Use of video cameras are in general less effective than direct observation because of their inability to provide localised non-visual cues, such as auditory ones (vocalisations) and provide the fine detail that is necessary to discriminate for example between a lesion and a smear of dirt on the skin. Automation should be utilised to assist the stockperson in monitoring animals and their conditions however, automation is unlikely, in the foreseeable future, to completely replace the stockperson. In the interests of animal welfare alone, the general public probably considers careful observation of animals under the stockperson's care as an essential part of good stockmanship. While not necessarily a legal requirement, codes of practice for farm animals in many countries state that daily observation of animals in confined conditions is essential. Another potential problem for animals that are deprived of human contact is the fact that if human contact is required, perhaps in an emergency situation, this interaction will be highly fear-provoking and aversive.

When moving animals and even when inspecting animals, human-animal interactions have considerable potential to influence the animals' fear of humans. For example, in many livestock species fast speed of movement and unexpected movement or appearance by the stockperson can elicit high fear responses in animals (Hemsworth and Coleman, 1998), including dairy cattle (Breuer et al., 2000). Human-animal interactions also occur in situations in which animals must be restrained and subjected to management or health procedures. The association of fear and pain from these husbandry procedures with humans performing them will increase the fear of humans which animals exhibit in other situations, such as during routine inspections. The effect these procedures have on the human-animal relationship relates both to the aversiveness of the procedure, and the association of people with that aversion. Rewarding experiences, such as provision of a preferred feed or even positive handling, around the time of the procedure, may ameliorate the aversiveness of the procedure and reduce the chances that animals associate the punishment of the procedure with humans (see Hemsworth and Coleman, 1998).

It is most likely that stockpeople will continue to interact with livestock in the future. Even if an opposing case could be mounted, no cost-benefit analysis of eliminating the stockperson has been done and, given the capital cost of many alternatives, it is unlikely that eliminating stockpeople would be practical. Therefore in order to maximise the opportunities to benefit from the stockperson's input into livestock production including intensive grassland production, it is important to train and select stockpeople to improve human-animal interactions and Hemsworth and Coleman (1998) have reviewed this important consideration.

Climatic conditions

Intensive grassland production may influence the opportunities for animals to shelter from climatic extremes and thus the influence of climatic conditions should be considered. The effects of the thermal environment on animal comfort and welfare are influenced by the age and stage of the reproductive cycle. The period of 2-3 days following birth represents the most critical period for the survival of newborn animals. About 50 % of calf mortality and 75 % of lamb mortality occur within the first postnatal day (Obst and Day, 1968; Theriez, 1982). Cold appears to be a major cause of death; a survey by Houston and Maddox (1974) suggested that about 50 % of the neonatal mortality of lambs could be attributed to cold and cold-induced starvation. In Canada, Jordan *et al.* (1969) reported a mortality rate of 8 % and 50 % of calves born indoors and outdoors, respectively.

For example, lambs and calves are relatively cold sensitive at birth (Collier *et al.*, 1982), due to their relatively larger surface area than adults, lack of heat production from rumen fermentation and being wet from foetal fluid. Thus, their ability to maintain a normal temperature is largely dependent on their capacity to produce heat; without feed the theoretical starvation survival time is calculated at 11 hours for lambs and 55 hours for calves (see Le Dividich *et al.*, 1992). As well as being dependent on colostrum for energy for heat production (Le Dividich *et al.*, 1992), the effects of heat and cold in young lambs and calves can also have indirect effects on the immune system; heat reduces serum gamma-globulin concentrations (Stott *et al.*, 1976), and cold affects immunoglobulin transfer in colostrum (Olson *et al.*, 1980) in dairy calves. Furthermore, there may be behavioural effects, for example in severe cold stress, colostrum intake may be reduced in the newborn lamb through a reduced teat-seeking activity (Alexander and Williams, 1966) or through a decrease in milk production by the ewe (Thompson, 1983). Other contributing factors in lambs are a low body weight, combined with the effects of a relatively large surface area and lower body reserves, reduced thermal insulation due to a lower pelage population density and shorter hair fibre length (Alexander, 1974) and premature or prolonged birth (Menissier and Petit, 1984, Vermorel *et al.*, 1989a). Differences in cold resistance are also affected by genotype in lambs (Slee, 1981) and calves (Vermorel *et al.*, 1989b) and are attributed to the animal's capacity to conserve and/or produce heat.

In contrast to the young animal, the adult is adversely affected more by heat than cold with relatively small effects on welfare provided the increased metabolic requirements are met by increasing feed intake, although there can be effects on milk composition (Ludri, 1983; Yamagishi *et al.*, 1984; 1985). A climatic factor often associated with cold conditions is wet weather and this variable appears to be associated with increased lameness in dairy cows (Williams *et al.*, 1986). While cold has minimal effects on reproduction (Vincent, 1972;

Moberg, 1976), heat can have adverse effects in a number of ways including adverse effects on duration of oestrus, conception, uterine function and early embryonic and foetal development (see Collier *et al.*, 1982 for a review). Heat is a major constraint on animal productivity in arid zones with adverse effects on growth, milk production and reproduction.

Under high heat loads one of the principal responses is to lower metabolic heat production by reducing feed consumption associated with significant metabolic changes (Niles *et al.*, 1980). Under these conditions, there is a negative nitrogen balance and tissue catabolism, in part due to a rise in cortisol concentrations during acute heat stress (see Alnaimy *et al.*, 1992). Such an effect on nitrogen balance and body weight contributes to a reduction in fitness and within this concept contributes to reduced welfare. A compromise in growth through excessive heat in intensively-managed animals is often considered a welfare problem. However, the public's general attitude to the welfare of animals in grassland production systems is less negative than that towards animals in intensive indoor systems and therefore there would probably be argument over the magnitude of this issue in contributing to reduced welfare. Breed selection is important in hot environments; Brahman cattle showed a steady increase in body weight with rising environmental temperature (Ragsdale *et al.*, 1951).

There is considerable literature on the effects of high temperatures on lactation with negative effects of high temperature on milk yield and composition (see Roman-Ponce *et al.*, 1977; (Ingraham *et al.*, 1979; Roman-Ponce *et al.*, 1981). Dairy cows increase their respiration rate and rectal temperature when exposed to high environmental temperatures and these responses have been used as a measure of animal comfort and adaptability to an adverse environment or as a measure of the efficacy of environmental modifications (see Roman-Ponce *et al.*, 1977).

Environmental modifications such as air conditioning, evaporative cooling and the provision of shade have been used with differential success to ameliorate the adverse effects of heat (see Roman-Ponce *et al.*, 1977). The simplest environmental modification is the provision of shade to reduce the heat load by reducing solar energy. Reduction of the total heat load can be up to 50% and the features of well-designed shade for cattle have been reviewed (Blackshaw and Blackshaw, 1991). However, responses in respiration rate, rectal temperature and milk yield have been equivocal (see Roman-Ponce *et al.*, 1977 and Blackshaw and Blackshaw, 1991).

Studies by Ingraham *et al.* (1979) and Roman-Ponce *et al.* (1981) showed increased milk yield and lower plasma corticosteroid concentrations in natural environments with shade than with no shade. However, further research is required to determine the fluctuations in intensity and duration of environmental variables that contribute to a chronic response to heat. High temperatures can adversely affect reproductive performance both directly and indirectly. Direct effects of hyperthermia can be death and resorption of embryos in early pregnancy and abortion of well-grown foetuses and depressed libido in males (Van Heerden, 1963). Indirect effects in females are potential increases in age at puberty, oestrous cycle length, duration of oestrus, incidence of abnormalities of the ova and foetal size (Hafez, 1968), as well as increases in the incidence of oestrus with weak signs, percentage of silent heat and ovulation failure (Mohamed, 1974). In males testicular function can be depressed affecting semen quality (Van Heerden, 1963) through effects on spermatogenesis and semen degeneration processes (Coser *et al.*, 1979), reduced ejaculate volume and sperm activity, concentration and viability (Coser *et al.*, 1979; Gamcik *et al.*, 1979). All the above effects reduce the fitness and contribute to reduced welfare in reproducing animals under high heat loads, although genotype can affect the environmental temperatures at which adverse effects occur, with European breeds being less resistant (Kibler, 1962; Bianca, 1963).

Whether a heat load constitutes a stress of sufficient magnitude to affect welfare is probably a function of a number of environmental variables, including temperature, humidity and air speed and their interaction with duration of exposure. Nevertheless, in many countries in which there is extensive grazing, summer temperatures and associated conditions of humidity and wind are often likely to be such that adverse effects on production and an associated acute stress response are likely to occur (Hinch, 1994) and the provision of shelter could ameliorate these effects.

Conventional husbandry procedures

For all species there are a number of common concerns that have general effects on animal welfare including health and disease, access to food and water, stocking density, paddock rotation, choice of breed and predation and these are considered as general management issues and not dealt with in this paper. There are also specific impositions on animals that will be discussed, including amputations (disbudding/dehorning, castration, tail docking and mulesing), induced parturition and transport.

a. Amputations

There are a number of amputations routinely performed on farm animals, including tail docking, castration, de-horning and mulesing. Tail-docking (amputation of tails) of dairy cows is a common practice in a number of countries including Australia, New Zealand and Ireland, while castration of male animals is common in meat animals. Tail docking, castration and mulesing can all be performed at the one time at a few weeks of age in sheep and dehorning/disbudding is a routine procedure in both dairy and beef cattle. A number of methods have been used to assess the welfare implications of these procedures including behaviour, physiology and electroencephalograms (EEG).

Tail docking of cattle raises the issues of acute and chronic pain (Petrie, 1994) associated with the practice *per se* and interference with grazing behaviour, through lack of a tail under conditions of high fly load (Ladewig and Matthews, 1992; Phipps *et al.*, 1993). A major justification for docking in cattle appears to be udder hygiene and farmer health (e.g. transmission of leptospirosis), although there is little evidence to support this (Wilson, 1972; Carsons, 1992). Other suggested reasons for tail docking of dairy cows include milk quality, milk production and health (Elliot, 1969; Middleton, 1997). This practice has been prohibited in the UK (Ewbank, 1988).

In sheep (lambs) the welfare implications of tail docking and castration centre on pain. A number of authors have concluded that the use of rubber rings results in more pain than surgery based on behavioural data, such as increased restlessness and lying in abnormal positions (Molony and Kent, 1993) and increased stamping and lifting the hind feet, pushing and butting each other and rolling on their backs, slower walking and less exploratory and social behaviour (Shutt *et al.*, 1988). Molony and Kent (1993) also concluded that rubber rings plus crushing with a Burdizzo clamp (a device that crushes the neural tissue) was the least painful method. However, the efficacy of the Burdizzo clamp on cortisol concentrations depends on how it is applied (Dinnis *et al.*, 1997). It remains to be seen whether restlessness is an appropriate behaviour to indicate pain, or if it only indicates discomfort. Alternatively, it is possible that an animal in pain may prefer to remain immobile to avoid irritation at the site of treatment or to disguise signs of pain. Similarly, the physiological data suggest that, irrespective of the procedure, castration was more stressful than tail docking, based on the greater cortisol response (Lester *et al.*, 1991a; Shutt *et al.*, 1987; Mellor and Murray, 1989).

Studies that compared the use of rubber rings and surgery for tail docking and castration found that surgery caused a higher (Lester *et al.*, 1991a) and longer (Lester *et al.*, 1991b; Kent *et al.*, 1993) cortisol response than rubber rings, suggesting that surgery is more painful to the animal. However, both anaesthesia and haemorrhaging may result in elevated cortisol concentrations and these factors, rather than pain *per se*, may in part explain the observed differences.

A recent study by Jongman *et al.* (2000) using EEG, found that at the time of the procedure the responses to tail-docking, castration and mulesing were similar, but 15 minutes later the responses to tail-docking and castration were different to mulesing. This finding, that mulesing is possibly more painful than tail-docking and castration is similar to that of Shutt *et al.* (1987), based on longer term measurements of cortisol and β-endorphin concentrations. Tail docking and mulesing resulted in a significant reduction in growth rate, although liveweight was not different by 5 months of age (Lear *et al.*, 1974).

In contrast to sheep, there is little literature on the welfare implications of the procedures in dairy cows. Petrie *et al.* (1993) and Petrie (1994) compared ring and surgical docking of 3-4 month-old Friesian dairy calves with and without local anaesthetic and concluded on the basis of both plasma cortisol concentrations and behaviour that the practice of using rings was similar to that of control handling and blood sampling. In a study on castration in calves using rubber rings and surgery, Fell *et al.* (1986) showed that, as in sheep (see above), surgical castration resulted in a greater cortisol response. On the basis of their behaviour, the surgically castrated calves were more agitated during the operation and took longer to return to normal grazing. Robertson *et al.* (1994) showed a similar response in that cortisol concentrations were highest after surgery, although this was not statistically significant. In this study, Robertson *et al.* (1994) compared three methods of castration (rubber ring, surgery and Burdizzo clamp) in animals of three ages (6, 21 and 42 days). Castration by rubber ring elicited the highest increase in active behaviour and abnormal posture, but the lowest cortisol response. The Burdizzo clamp caused the earliest and shortest cortisol response, although the peak response was higher after castration with rubber rings. The response was also higher in older calves.

Horn growth in dairy cattle is prevented by destruction of the horn bud when animals are young. Disbudding is a common management practice in the dairy industry in many countries as animals without horns are less likely to injure herd mates or handlers. A variety of procedures are used including application of a hot iron or caustic chemicals to the bud. Although the use of local anaesthetic has been recommended (Booth and McDonald, 1982) to provide pain relief during the removal process, it is not routinely used. Cortisol concentrations were elevated for up to 1 h following disbudding with an electrically heated device in comparison with animals handled but not disbudded (Laden *et al.*, 1985). In a subsequent study, administration of a local anaesthetic did not prevent the disbudding-induced rise in cortisol concentrations (Boandl *et al.*, 1989), although more recent studies have shown that local anaesthetic delays the increase in cortisol concentrations associated with scoop dehorning, presumably until the anaesthetising effects wear off (McMeekan *et al.*, 1998). The level of stress and pain may be further reduced by combining local anaesthetic and cautery (Petrie, 1994; Sylvester *et al.*, 1998).

While these data suggest that the issue of acute effects is probably real and can be modified by methodology, the possibility of chronic effects is totally unresolved. Traumatic neuromas, often used as being indicative of chronic pain, invariably develop after limb amputation in humans, in beak stumps after trimming of domestic poultry, depending on their age (Breward and Gentle, 1985; Gentle, 1986; Lunam *et al.*, 1996), and in tail stumps of pigs after docking (Simonsen *et al.*, 1991). Nevertheless, it is also possible that traumatic neuromas and, as a consequence, chronic pain may exist following amputation of tails and horn tissue in cattle, and tail and testicular/scrotal tissue in sheep. In fact there is evidence that adult cows that were docked using a knife when 12-18 months old had neuromas in their tail stumps when slaughtered after 3 years of age (C. Lunam and J. Barnett, unpublished data). It remains to be determined if other methods of docking, age at docking and removal of differing amounts of tail also result in the long-term presence of neuromas and whether there is any associated chronic pain. Similarly, the use of a local anaesthetic appears to diminish the magnitude of behavioural and physiological responses during some of the operations and appears to reduce pain associated with the procedures. While the use of analgesics is certainly not widespread in agricultural industries, it is likely that analgesics may be required in the future to minimise pain associated with husbandry procedures for agricultural species. Further research is required to determine the effectiveness of anaesthetics or analgesics in providing post-operative pain relief.

b. Induced parturition

Induction of calving is widely practised in the Australian and New Zealand dairy industries. Dairy farming in these countries involves grazing cows outdoors all year round and induced calving allows farmers to concentrate the calving pattern so that lactation coincides with feed availability. Furthermore, with the post-partum anoestrus period and sub-optimal pregnancy rates, the practice of induced calving allows herds to maintain a 365-day calving interval. It is estimated that up to 20% of cows are induced into calving in Australia and New Zealand and that most dairy farms use this practice to manage reproduction. The treatment regimen commonly used involves an initial injection of a slowly-absorbed corticosteroid formulation followed, if necessary, 7 to 12 days later by an injection of either a rapidly-absorbed corticosteroid or a prostaglandin analogue (MacDiarmid and Cooper, 1983). While the efficacy of this treatment on the induction of calving has been widely studied, little research has been conducted on the consequences of the treatment on the welfare and health of cows and their calves.

Although estimates on mortality of the induced calves varies widely, several studies have found high mortality rates in calves following induced calving. In a large scale Australian study, there was a mortality rate of 38.5% in 709 calves produced by induction with a dexamethasone preparation and a 2.7% mortality rate among 4330 calves from normal parturition (Allen and Herring, 1976). In studies on small numbers of animals, the use of dexamethasone preparations in mid to late pregnancy resulted in calf mortality rates ranging from 13.5 to 35.0% (Adams, 1969; Welch *et al.*, 1973; Murray *et al.*, 1982; MacDiarmid, 1979, 1980). In contrast, other studies have reported no increase in calf mortality with induced calving (Jochle *et al.*, 1972; Beardsley *et al.*, 1973). The high mortality rates in some studies may have been due to cows being induced early in gestation, and indeed several authors have reported that calves produced by cows induced prior to 270 days gestation are less viable (Carroll, 1974). Furthermore, O'Farrell and Crowley (1974), reported that the 26.0% stillbirth rate in calves from cows treated with dexamethasone preparations occurred entirely in those cows in which induction occurred before 260 days of pregnancy. Prematurity may result in less efficient uptake of colostral immunoglobulins (Johnston and Stewart, 1986). Thus induced calving, particularly the production of very premature calves, may produce animals which may be extremely light in weight, have thin coats, have difficulty standing and which may be lethargic and poorly motivated to suck the cow's teats.

The second welfare concern is the effect of the procedure on the health of the cow. Endogenous cortisol concentrations are suppressed in cows for up to 29 days after treatment and do not appear to be compensated for by the synthetic glucocorticoids which are only detectable for up to 14 days (Fairclough *et al.*, 1981; MacDiarmid and Cooper, 1982, 1983), although a sustained reduction in eosinophil numbers, as indicated in the study by MacDiarmid and Cooper (1982), suggests some residual glucocorticoid activity. This may leave the animals with a seriously impaired ability to counteract the challenge of stressors, including disease, following parturition. Indeed, in cows induced to calve by corticosteroid treatment, cases of metabolic disease are sometimes less responsive to treatment (MacDiarmid, 1980). In an extensive comparison of cows induced to calve with those of similar calving dates and ages but not induced to calve in 51 herds, Morton and Butler (1995a) found a higher incidence of dystocia in induced cows and a higher incidence of clinical disease and mortality in induced cows aged over 6 years. There is also evidence in induced cattle of an increased incidence of retained foetal membranes (Allen and Herring, 1976; MacDiarmid, 1979, 1980; Murray *et al.*, 1982; Morton and Butler, 1995a), and, while retained foetal membranes can contribute to reproductive problems, the evidence on the effects of induced calving on post-calving fertility is contradictory. A number of studies have found no association between induced calving and post-calving fertility (eg Bailey *et al.*, 1973; Allen and Herring, 1976; Morton and Butler, 1995b), while others studies have found associations between induced calving and reduced fertility (eg Moller and MacDiarmid, 1981, Hayes et al., 1998). While these retrospective studies provide conflicting results, Bellows et al. (1994) found that pregnancy rate was reduced following induced calving in a controlled experiment examining the effects of induction on reproduction in beef cows.

Therefore, there are some specific impositions on animals such as amputations, induced parturition and transport, that may challenge homeostasis, at least in the short term, and thus may compromise animal productivity and welfare. Further research will be valuable in minimising these risks.

Biotechnological manipulations

Economic pressures on the livestock industries will lead to further development of new animal genetic and reproductive technologies aimed at increasing the rate at which new genetic lines of animals can be bred to produce new or modified livestock products. There are two general opinions concerning biotechnological development in the livestock industries. One is that there is considerable hype and the outcomes will not meet people's expectations. The other is the likelihood of large numbers of biotechnological interventions in livestock.

In addition to ethical concerns, consumers are likely to demand that the animal welfare implications of such developments are properly evaluated by an independent organisation before implementation. The welfare concerns are likely to relate to the experimental animals in which these manipulations are being developed and studied and secondly, the welfare consequences for the commercial animals in which the developed manipulations are subsequently applied. A number of authors have argued that biotechnologies, such as genetic engineering of animals, have already caused animals to suffer. For example, Fox (1988, 1989) suggested that problems such as developmental abnormalities, new health problems, disease resistance and genetic disorders are examples of suffering already encountered in transgenic animals. Manipulations that have come under scrutiny by the public include the use of bovine somatotrophin, super-ovulation, repeated pregnancy diagnosis, embryo transfer, increased twinning and genetic engineering. While most of these manipulations probably raise concerns about the pain associated with the procedure or its consequences, genetic engineering raises an additional concern. An animal develops throughout the whole of its life and must be well adapted to its environment in order to not only survive but to grow and reproduce normally and remain healthy. Genetic manipulations may affect behavioural development and in turn the productivity and welfare of the animal through difficulties for the animal in adapting to its environment.

The welfare implications of biotechnology must be incorporated into these programmes at an early stage. If the current situation continues in which animal welfare is only considered at the end of the biotechnological development, public scepticism of the technologies will, at the least, not be assuaged. Such ethical concerns by the public and in particular the consumer can limit the commercialization of biotechnological developments and, as in other industries, the animal welfare implications of the development require consideration.

Other challenges

The are a number of other challenges with intensification of grassland production that need to be contemplated. For example, intensive grassland systems may impose serious time constraints on the capacity of animals to engage in maintenance activities. As herd size increases, dairy cattle on pasture spend increasing time walking to and from the dairy and standing in the holding yards prior to milking. Furthermore, pasture may not provide the nutritional requirements needed to maintain high milk yield in dairy cows because of variability in pasture quality and quantity and indeed high yielding cows spend much less time lying down and significantly more time grazing (Albright and Arave, 1997). In addition to grazing, drinking and elimination, dairy cattle also require time for comfort behaviours such as resting, sleep, shelter seeking, licking, nibbling, scratching, rubbing and mutual grooming. Animals appear to be highly motivated to perform these comfort behaviours and thus the question is whether or not they suffer during deprivation. There is some limited evidence that lying deprivation may activate the HPA axis. In addition to an increase in biting and licking pen fixtures, Munksgaard and Simonsen (1996) found that dairy cows that were deprived of lying had elevated ACTH concentrations. As grassland systems become more intensive, the effects on the time budgets for maintenance activities need to be considered.

An increasing concern in pasture-based dairy production is the use of genotypes selected on high energy diets. Kolver et al. (2000) reported that Northern Hemisphere Holstein Friesian genotype produced the same yield of milksolids in an all-pasture system as the New Zealand Holstein Friesian genotype but the former genotype failed to maintain body weight in this production system. Webster (2000) has also argued that longevity and welfare are risk in these high genetic merit dairy cows particularly on pasture when metabolic stress is likely to arise with the imbalance between energy input and output. Breeding and management strategies are required to avoid stress due to high metabolic load in such situations.

Conclusion

The increasing need to produce cheap and safe animal products as the world's population increases is likely to result in greater intensification of grassland production systems for livestock. Challenges to the ability of the animal to adapt to increased intensification of production may reduce animal comfort and in turn reduce animal productivity and welfare. In addition to the production implications of the behavioural and physiological responses that animals may use to try to restore homeostasis, difficult or inadequate adaptation will also generate animal welfare problems. There are a number of factors that will affect animal comfort with the intensification of grassland systems for livestock. These factors include the social environment, human interactions, climatic conditions, conventional husbandry procedures, new biotechnological manipulations and unsuitable genotypes. Both group size and space allowance are key features of the social environment that may affect animal comfort, while the amount and nature of human contact are important factors, which through fear, may also affect animal comfort. Thermal stressors can have a significant impact on animal comfort with cold around parturition being a serious problem for the offspring and heat having adverse consequences for adult animal production and comfort. The concerns for animal comfort over husbandry procedures include practices ranging from simple interventions such as shearing that involve the challenges of restraint, close human contact and isolation to more complex surgical interventions such as tail docking and castration that may include the additional challenge of acute and chronic pain, as well as short-term production depressions. Others issues include risks associated with animal biotechnologies, including simple manipulations such as twinning to more complex transgenic manipulations. Since intensive grassland systems are likely to continue to develop in the future, it is important that factors that are likely to be problematic are evaluated and addressed because of the implications of animal comfort on animal productivity and welfare.

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