211. Broom, D.M. 1995. Measuring the effects of management methods, systems, high production efficiency and biotechnology on farm animal welfare. In: *Issues in Agricultural Bioethics*, ed. T.B. Mepham, G.A. Tucker and J. Wiseman, 319-334. Nottingham: Nottingham University Press.

In Issues in Agricultural Bioethics ed. T.B. Mepham, G.A. Tucker and J. Wiseman, 319-334. Nottingham: Nottingham University Press, 1995.

20

MEASURING THE EFFECTS OF MANAGEMENT METHODS, SYSTEMS, HIGH PRODUCTION EFFICIENCY AND BIOTECHNOLOGY ON FARM ANIMAL WELFARE

D.M. BROOM
Department of Clinical Veterinary Medicine, University of Cambridge, Madingley Road, Cambridge CB3 0ES, UK

Introduction

The concept of animal welfare as 'the state of an individual as regards its attempts to cope with its environment' (Broom, 1986) allows a measurement of how good or poor welfare is. The range of measures outlined in this chapter are described in greater detail by Broom (1988, 1991a), Fraser and Broom (1990) and Broom and Johnson (1993). It has become important for the public image of the agricultural industry, for accurate information of the general public, and for legislation that precise scientific studies of animal welfare be carried out. Hence, there has been a proliferation of research studies in this area, examining both established and novel aspects of farm animal production.

This chapter includes details of some of the methods of welfare assessment and some examples of their use. This is followed by data on the effects of production efficiency on animal welfare (see also Broom, 1994) and a survey of the limited information available about the welfare of animals which are treated with the products of recombinant DNA technology or genetically modified.

Measures of welfare: Preference studies

In order to develop good systems for the housing and management of animals it is of particular importance that studies of the preferences of animals be carried out. It is essential to know what is important to animals if they are to be treated in a humane way. Observations of how animals spend their time when they are in a rich environment are a useful preliminary guide in designing accommodation. However, in order to use such information it is necessary to know how strong a preference is. An animal might consistently prefer one kind of food to another but both might be nutritionally adequate and the extent of suffering if the non-preferred food is given might be minute.

Techniques are available to assess the importance of preferences, for example those described by Dawkins (1983, 1990) and Duncan (1987), Duncan and Kite (1987). Pigs can be required to press a lever for temperature modification, or for access to earth for rooting or straw for nest-building. The number of presses for reward then indicates the value of the reward. Duncan and Kite's hens pushed a door with weights on it to gain access to a resource. Dawkins' hens had to choose between feeding and litter access. Such studies allow new systems to be designed, which can then be compared with existing systems. Very many aspects of farm animal management need to be looked at in this way but, as Dawkins (1990) emphasises, the experiments must be carefully designed.

Preference studies cannot give all the answers to questions about animal welfare, even though they give a great deal of information about the likelihood that animals will suffer. When an animal shows preference for a certain food or level of eating, for example, it may be mistaken in its choice and its welfare may become poor. Anorexic girls have a very strong preference not to eat, to the detriment of their welfare. Rats in 'cafeteria' experiments, or indeed some people, may eat chocolate bars exclusively, with the result that they become short of some nutrients and obese, so their welfare becomes poorer. People may choose to take drugs that damage them and masochists deliberately injure themselves. In several of these cases the individual is choosing for short-term reward but is making the wrong choice for the long-term. As Mendl (1990) has pointed out, choices may depend very much on the experience of the individual during development and may not improve welfare. Preferences will also change with physical conditions, so a pig may strongly prefer to lie on straw in cold conditions but may prefer a wet floor in hot conditions.

There are some important welfare problems where preference tests are difficult to use. Long-term housing conditions may be difficult to assess in this way because the animal may be substantially modified psychologically by the conditions. Preference studies are difficult to use when the animal is ill or when the object of the study is to compare modified and unmodified animals. It is important to try to find out about the animals' feelings but the modification may have affected the ability of the animal to have such feelings as well as the ability of the animal to cope or the extent to which it has to show coping behaviour. For example, a transgenic procedure could result in an individual being attracted by conditions much hotter than those which a normal individual would find attractive and which would quickly cause tissue damage. Alternatively, the pain system could be modified in a transgenic individual so that the normal, important, protective function of pain with its associated responses might alter preferences for or against situations that might be painful. Hence, in transgenic animals, studies of positive preferences could give ambiguous results. Negative preferences, or aversion behaviour, can usefully be studied but should also be interpreted carefully, taking account of other welfare measures.

Measures of welfare : Indicators of the extent of poor welfare

All of the measures described below give information about welfare and the order of listing them is not an order of importance. The first two measures are of poor welfare associated with fitness reduction while the remaining measures need not indicate fitness reduction, although they could do so. They indicate how poor the welfare is by showing how much difficulty the individual has in trying to cope with its environment or how aversive it finds some aspect of its environment.

A general problem with studies of transgenic animals is that the genetic manipulation could have directly affected the particular functioning of the body that is monitored using a welfare indicator. A hypothetical example is that the insertion of a gene increasing prolificacy might reduce the amount of adrenocorticotrophic hormone that is produced in the anterior pituitary for a given level of corticotrophin releasing factor. This would result in lower levels of plasma glucocorticoids in a variety of emergency situations. As a consequence the individuals might be less well able to show appropriate action in such circumstances and might therefore show a greater degree of abnormal behaviour and more tissue damage. It will clearly be difficult to use particular measures if there are such effects but care must be taken in any study to try to ascertain the extent to which such effects have occurred.

LIFE EXPECTANCY

If one management method results in a shorter life expectancy than another, the welfare is poorer when the former method is used (Hurnik and Lehman, 1988; Broom 1991a). The majority of people would regard the animal which has a shorter life, perhaps living at a higher rate, to be under greater stress than that which lives longer, perhaps at a slower rate. The best known examples are captive wild animals like cetaceans, whose life expectancy in small zoo pools is short. As most dairy farmers know, the life expectancy of dairy cows is shorter now than it was 20 years ago and Agger (1983) reported that in Denmark it had halved between 1960 and 1982 (Figure 20.1). Since the animals concerned had

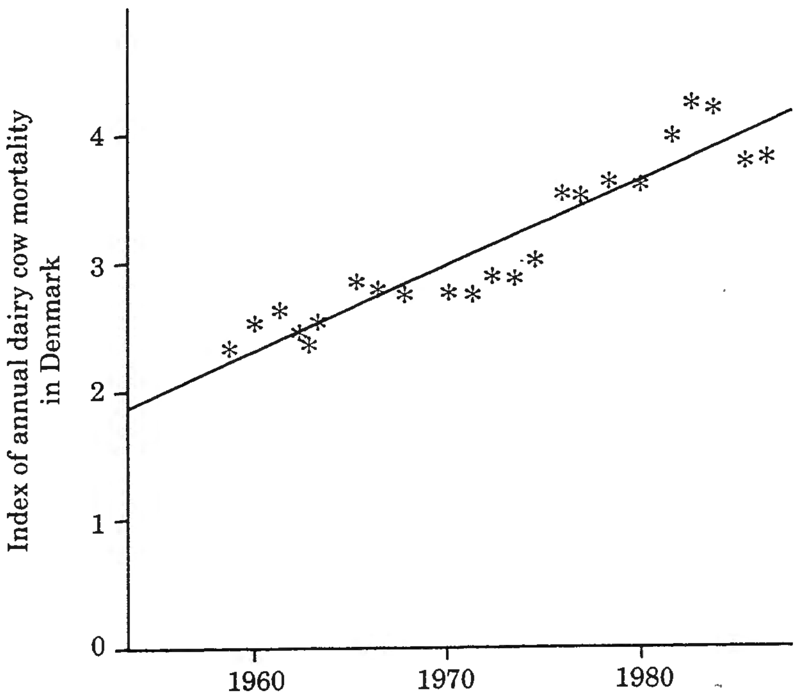

Figure 20.1 The rate of mortality of dairy cows in Denmark doubled over a period of 20–25 years so the life-expectancy of a cow halved (after Agger, 1983).

all been sent to rendering plants, much of the increased mortality must be a consequence of increased metabolic rate and feed conversion efficiency leading to more production related disease, reproductive problems and actual mortality. Any further factor which increased metabolic pressure on the cow, as bovine somatotrophin injection could, would probably reduce life expectancy still more.

REDUCED REPRODUCTIVE SUCCESS

Inability to reproduce may be evident from studies of physiology or behaviour or it may only be demonstrated by large-scale comparative studies. When the effects on welfare of housing and management of animals are studied, the welfare of individuals that are unable to reproduce, or whose reproductive success is seriously impaired because of those conditions, is poorer than that of individuals not so affected. For example, some animals are seldom or never able to reproduce after pairing in zoo conditions and inappropriately reared farm animals may fail to breed (Houpt, 1984; Beilharz, 1985; Price, 1985). This measure of welfare could also be used in most studies of the effects of biotechnological procedures, the only difficult area being that in which a transgenic procedure results in direct modification of the reproductive system. Some modifications of the reproductive system would have an inevitable effect on reproductive success so this measure would not be valid. For example a procedure that resulted in immunocastration would obviously reduce reproductive success and such effects should be differentiated from effects on reproduction of stress which was an accidental consequence of a biotechnological procedure.

WEIGHT CHANGES

Another indicator of poor welfare is depressed weight gain in young animals, for example piglets, or abnormal weight loss in adults. The measure must be used carefully, however, because a temporary loss of weight in a rutting stag or a lactating mother which has gained much weight before parturition, would not be construed as indicating poor welfare. Neither would the welfare of an obese young pig be regarded as better than that of a normal pig. Some biologically relevant standard must be used in such assessments.

DISEASE INCIDENCE AND ANATOMICAL DEFECT MEASURES

Direct measurement of disease occurrence and studies involving experimental disease challenge also give information about the welfare of animals. One example of a study of farm animal management procedures in relation to disease incidence is that of Ekesbo (1981), while the series of studies by Gross and Siegel (e.g. 1981) on the susceptibility of chickens to disease challenge demonstrated that social mixing results in increased adrenal activity with consequent immunosuppression and increased susceptibility to many diseases. Any increase in disease incidence necessarily means poorer welfare but careful comparisons must be made in order to be sure of the exact cause of a higher level of disease in animals of a particular genotype or animals treated in a particular way.

Recent work on hens has shown that those reared in battery cages with insufficient opportunity for exercise have weak bones (Knowles and Broom, 1990; Norgaard-Nielsen, 1990) and that the bones are much more likely to be broken during handling before slaughter than are the bones of hens which get enough exercise. The possibility of anatomical effects of this kind should be investigated in genetically modified or treated animals. Changes in anatomy should be described and any effect that reduces the animal's ability to cope with its environment should be considered to be an indicator of poor welfare. Just as immuno-suppression is an indicator of poor welfare even in the absence of disease challenge, weak bones or some other anatomical change which renders the animal more vulnerable to damage or to frustration because of some inability, are also indicators of poor welfare. The welfare of the animal with weak bones is poorer than that of the animal with normal bones but the welfare is much poorer if there is bone breakage and suffering (Broom, 1991b). Even those who would not consider that welfare is poor until the bone is broken would generally advocate measurement of bone strength, or other measures of this kind, as being desirable in relation to welfare assessment.

HEART RATE AND BLOOD MEASURES

Heart rate measurement is of particular value when assessing welfare in the short-term, so a genetic modification or treatment that changed anatomy in such a way that it caused localized pain or movement difficulty might be detectable in experiments by measuring brief increases in heart rate. General sampling of heart rate gives little information about long-term welfare problems.

Several measurements of blood composition have been used when welfare assessment is intended but most have shown no consistent relationship with other measures. Counts of eosinophils indicated the severity of the effects of repeated immobilization of mink (*Mustela vison*) (Jeppesen and Heller, 1986) but these responses were to short-term problems and it is not clear that the measure would be of much use in assessing long-term effects on welfare.

ADRENAL FUNCTION MEASURES

Adrenaline released from the adrenal medulla disappears from the blood within a few minutes and glucocorticoids secreted from the adrenal cortex are usually removed from the blood in less than an hour. As a consequence, random sampling of blood for these hormones is unlikely to be of use when assessing welfare in the long-term. However, as with heart rate, responses to localized discomfort or intermittent movement difficulties can be assessed readily by measuring levels of adrenal cortex hormones. Most of such work has involved the measurement of glucocorticoids in plasma, but care must be taken to ensure that the sampling does not, itself, cause the changes measured. Sampling of saliva is sometimes easier and levels of free glucocorticoids in saliva can be assayed (Cooper *et al.*, 1989). Regular sampling of blood from cattle fitted with vascular catheters revealed that the number of cortisol peaks was different for different housing conditions (Ladewig and Smidt, 1989). Although a single peak does not necessarily mean that the welfare of the animal is poor, the presence of many peaks in blood levels of plasma cortisol indicates that the individual has often had to show an emergency reaction.

The fact that frequent, unpleasant stimulation, with consequent adrenal cortex activity, can result in greater activity of enzymes or other facilitation in the hypothalamic-pituitary-adrenal cortex axis (Restrepo and Armario, 1987) can be used in an adrenal cortex function test. Challenge with adrenocorticotrophic hormone (ACTH) has been shown to give greater cortisol responses in farm animals after close confinement (Friend *et al.*, 1977; Dantzer *et al.* 1983), high stocking density (Meunier-Salaun *et al.*, 1987) and frequent loss in social encounters (Mendl *et al.*, 1991; Mendl, Zanella and Broom, 1992b). The dexamethasone suppression test can also give useful information about the welfare of the individual in the period before testing (Mendl, Zanella and Broom, 1992a, b). However, as emphasized by Broom and Johnson (1993) more information is needed about how to interpret these tests.

MEASURES OF IMMUNE SYSTEM FUNCTION

Difficulties in coping with the environment can often be associated with some degree of immunosuppression (Kelley, 1985; Broom and Johnson, 1993). It is argued elsewhere (Broom, 1988, 1991b) that, in a comparison of two treatments, the welfare of animals whose immune system is suppressed is worse than that of individuals not thus affected. The welfare is even worse if there is disease and suffering as well as immunosuppression

Immunosuppression can be measured by white cell counts, especially by counts of categories of T-lymphocytes. It can also be indicated by measuring the antibody response to an antigen challenge. Metz and Oosterlee (1981) challenged sows with sheep red blood cells and found the antibody response to be less pronounced in recently-tethered sows. Zanella, Broom and Mendl (1991) found that there

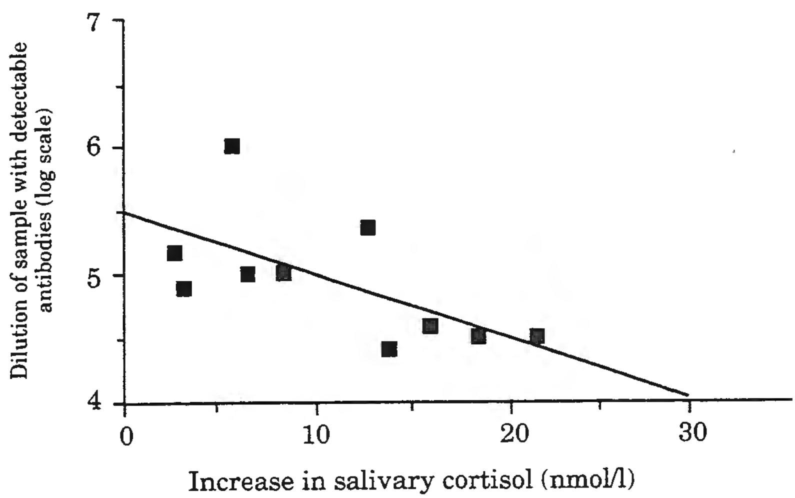

Figure 20.2 The relationship between the titre of tetanus antibody in sow colostrum and the level of salivary cortisol after 4 μg kg[-1] adrenocorticotrophic hormone injection (data from Zanella *et al.*, 1991a)

was a relationship between high response to ACTH challenge in sows and lower levels of antibody production to challenge with tetanus toxoid or atrophic rhinitis vaccine (Figure 20.2). Measures of T-lymphocyte function, which provide information about immunosuppression and hence welfare, are many and varied. Some techniques involve the use of a non-specific lymphocyte stimulator, such as phytohaemagglutinin (PHA) or dinitro-fluorobenzene, hence care must be taken in experiments to take account of the subjects' previous experience of antigens. Environmental conditions, such as high or low ambient temperature, have been shown to reduce the immunological response in such tests (Kelley *et al.*, 1982), so these tests might also be useful in assessing the effects of biotechnological procedures. More precise measures which can be carried out *in vitro* involve assessing the rate of lymphocyte proliferation in the presence of mitogens such as PHA, concanavalin A or pokeweed mitogen (e.g. Coe *et al.*, 1989). Assays of the efficacy of natural killer cells and of macrophages are also possible. Few of these procedures have been used in studies of farm animal welfare but it is of considerable importance to use measures of immunosuppression when assessing animal welfare.

OPIOIDS

Following the discovery that analgesia can be mediated by endogenous opioids (Hughes *et al.*, 1975) and that such opioids are produced by animals in a variety of difficult conditions, it became clear that self-narcotization was another potentially measurable way of trying to cope with the environment (Cronin, Wiepkema and van Ree, 1985; Broom, 1986; 1987). Studies of a variety of species including sheep (Shutt *et al.*, 1987) and horses (Taylor, 1987) have shown that blood plasma levels of the opioid β-endorphin increase after surgery and other treatments. However, these increases may have no relevance to any analgesic effect. Long-term changes in animals showing disturbed behaviour are different in respect of this measure, indeed the blood plasma β endorphin level in tethered sows measured by Wiepkema and Schouten (1992) was lower than the normal level for sows. Experiments using opioid inhibitors have given some results which are interesting, if difficult to interpret. Recent work in which the density of opioid receptors in parts of the brain has been measured are also particularly promising (Zanella, Broom and Hunter, 1991). As mentioned earlier, any study such as that in which opioid action in the brain is assessed would have to be interpreted carefully if the subjects are transgenic animals in which a direct effect on such mechanisms might occur.

BEHAVIOUR MEASURES

Frequently, the best indicators of long-term problems for an animal are measurements of behaviour (Broom and Johnson, 1993). Behavioural changes can be quantified just as precisely as physiological changes and the measurements can usually be made with less disturbance to the animal. For some measures, video-recording is desirable, since it is always necessary to record the behaviour for a long enough period and to compare it with an adequate number of controls. Abnormalities of locomotion are the simplest behavioural changes to record and they can indicate localized pain. Modified feeding, sexual or social behaviour can also be recognized if observations are carried out in appropriate test conditions.

If animals are unable to perform a behaviour that they wish to perform, or are otherwise frustrated, or are in a situation in which they have insufficient control over their interactions with their environment, a variety of behavioural responses may occur. The animal may show stereotypies, self-mutilation, excessive aggression, or inactivity and unresponsiveness. Any of these abnormalities might occur to a greater or lesser degree in genetically modified animals or in those to which substances are administered. For details of such behaviours see Fraser and Broom (1990) or Broom and Johnson (1993). There could also be abnormal behaviour which is caused by specific, localized, painful or irritating stimulation.

Many of the behavioural measures indicate that some general or specific aspect of the environment with which the animal interacts is aversive. Experimental assessment of aversiveness is also possible. Rushen (1986) found that sheep which had been driven down a race and had experienced something aversive at the end of it were considerably harder to drive down the race on subsequent days. Certain aspects of the environment might be more aversive to genetically modified or treated animals than to controls, for example if the effect of the procedure was to make eyes very sensitive to light or to cause difficulties in movement.

WHICH MEASURES SHOULD BE USED?

Ideally, a wide range of measures should be used in an investigation of welfare. However, some measurements take much longer to make than others, for example mortality rates. Certain of the measures, such as heart-rate changes, immediate adrenal cortex responses and some behavioural changes, are used only where there are short-term effects on welfare, for example when an individual with localized pain has to exercise beyond the point where the pain can be avoided. In most studies, it will be the long-term welfare measures that are the most important. A proper study would include: several measures of behaviour; some investigation of adrenal function and of immunosuppression; direct assessment of disease incidence and injury levels; measures of growth and measures of reproductive success. Only in such a wide ranging study will it be possible to take account of variations in individual response. The study should last for a long period since some effects may not be apparent for some time.

Possible effects of production efficiency and genetic engineering on welfare

The efficiency of animal production, both in economic terms and in terms of individual animal productivity, has improved dramatically in recent years and this improvement is generally beneficial for human consumers. In some ways, however, these changes have resulted in poorer animal welfare (Broom, 1994). Particular effort has been directed towards increasing growth rates by high levels of feeding, increasing food conversion efficiency and managing or modifying animals so as to obtain special products. Ways of achieving these objectives have included improved nutrition, manipulation by growth regulators and modifiers, changes in housing and daily management, conventional breeding and genetic manipulation.

Examples of the adverse consequences of aiming for fast and efficient growth are: leg problems, changes in disease incidence, changes in the proportion of muscle to blood circulation capacity (e.g. Dämmrich, 1987), increased survival of harmful genes and parturition problems. Special products may necessitate specific management procedures (e.g. for white veal) or breeding (e.g. for prolific wool production), which cause problems for the animals.

Economically viable animal production is possible without these adverse effects, and efficiency should not be increased if the result is poorer welfare. Some of the questions about the use of biotechnological products, such as somatotrophin and of transgenic procedures, relate to these points about the problems of increasing production efficiency. If any substance is administered to an animal, there could be an effect on how much the animal has to exert itself to cope with its environment, or on how well it copes. As explained above, both of these aspects are relevant to welfare. A substance might cause pain but no reduction in growth, survival chances or reproductive success; or it might reduce survival chances without causing any pain or discomfort. In either case, the welfare of the individual would be poorer than that of another individual that was not affected in any of these ways. The purpose of administering the substance may be to benefit the animal, for example to improve its ability to combat disease, or it may be to increase production or change the timing or quality of production of meat, milk, offspring etc. In either case, welfare could change for the better or for the worse. There can be short-term adverse effects on welfare, for example those caused by an injection, followed by long-term effects which are different. Both should be assessed and, where there are good and bad effects, as in injection of an antibiotic, an attempt should be made to evaluate the overall effect. A substance that affects growth rate, milk production or reproduction may also have short- and long-term adverse effects on welfare. The long-term effect on welfare could be neutral or beneficial but high rates of metabolism and growth can lead to joint problems and various production related diseases. These and other possible effects on welfare should be monitored thoroughly.

An animal that is changed phenotypically by conventional breeding procedures may have more or less problems in coping with its environment than its parents or earlier ancestors. The positive effects of reducing fear responses to man have been important in the domestication of animals. Negative effects include defects in dogs, which were allowed to continue because selection was aimed at producing physical characteristics in the dog that were aesthetically pleasing to some humans. In farm animals, examples of negative effects include those which have resulted from selection for double muscling in Belgian Blue and other cattle to the point where some strains can only be perpetuated by the frequent or inevitable use of Caesarean section. Selection for fast and efficient muscle growth in broiler chickens, pigs and beef cattle has resulted in a substantial increase in leg problems, because the leg structure does not develop as fast as the muscles.

If genotype changes are accelerated by the use of transgenic procedures, the chances that some effect on the welfare of individuals might occur will be increased. The gene or genes transgenically added to an existing farm animal genotype are very likely to be those which might increase production efficiency in some way. There must be some biological limit to the production efficiency that is possible with a particular body design and as this limit is approached system failure will be more frequent. Hence a further increase in efficiency in an already efficient animal is likely to have some adverse effects on welfare. Gene changes whose aim is to produce a relatively small quantity of a novel protein are less likely to cause problems and those aimed at increased resistance to disease may well have an overall beneficial effect for the animal. Whatever the aim of the gene change, however, a careful study of the welfare of the transgenic animal is necessary.

There could be many effects of genetic manipulation or of substance administration on an animal. Sensory functioning, structure of bones or muscles, hormone production, detoxification ability, neural control mechanisms or many other aspects could be affected. What is of concern here is not to ascertain whether there are effects, but to assess the consequences of all of these effects for the welfare of the individual. In order to do this, carefully controlled comparisons of modified or treated and control animals must be carried out. A wide range of measures of welfare must be used in such studies since there are many possible effects and individuals vary, both in their coping responses and in the extent to which they fail to cope (Koolhaas *et al.*, 1986; Mendl, Zanella and Broom, 1992b; Broom and Johnson 1993). A single welfare indicator could show that welfare is poor but absence of an effect on an indicator, e.g. on growth rate, does not show that welfare is good. For example, if the major effect was behavioural abnormality or increased disease susceptibility but appropriate measurements were not made and growth rate was not affected, spurious results could be obtained.

Demonstrated effects on welfare of genetic manipulation or substance administration

No comprehensive study, using an adequate variety of measures, of the welfare of transgenic animals or animals treated with substances produced by recombinant DNA technology has yet been reported in the scientific literature, although certain aspects of welfare assessment have been covered by Phipps (1989) and in papers by van der Wal, Niewhot and Politiek (1989). Certain transgenic animals have been so obviously affected in an adverse way that no detailed study of welfare was necessary. In many instances the animals did not survive long. The most widely publicized welfare problem was that of the Beltsville pigs carrying human or bovine growth hormone genes, which showed various pathological conditions including joint pathology, and whose locomotion, standing up and lying down appeared to be abnormal (Pursel *et al.*, 1989). Given the large number of transgenic animals that have been produced and the substantial amount of work on farm animal welfare carried out in recent years, it is surprising that programmes aimed at producing commercially valuable transgenic animals have not incorporated welfare assessment, at least in the latter stages of development.

Work on the effects of recombinant bovine and porcine somatotrophin injection has also been directed almost entirely towards finding out how to improve productivity in dairy cows and pigs. Any results which indicate the effects on the welfare of the animals have been derived largely as an incidental by-product of the main study. This rather short-sighted approach to the testing of bovine somatotrophin (bST) and porcine somatotrophin (pST) and lack of concern for the animals has been one of the causes of public disquiet about the use of these products.

Since bST occurs naturally, low levels of it are unlikely to have any adverse effects on welfare but, even at low levels, the effects need to be checked because each of the different forms of recombinant bST available has some difference in amino acid sequence from the natural form. bST injection results in increases in the amount of insulin-like growth factor-1 (IGF-1) in the blood and in milk (Prosser *et al.*, 1989; 1991; Prosser and Mepham 1989). These increases can be substantial and it has been shown that high levels of IGF-1 can affect rat bone growth (Juskevich and Guyer, 1990). Low levels of IGF-1 are likely to have no adverse effect but it is a potent mitogen and it is not known what effects high levels of it have on the cow, or on the calf which consumes the milk, or indeed on people who do so (Mepham, 1991).

The most clearly documented effects of bST are on disease incidence and on reproduction (Willeberg, 1993). The effects of bST injection are similar to changes that occur during the rising phase of lactation and high-yielding cows that are not treated with bST are particularly susceptible to disease at this time. Kronfeld (1988) states that high levels of bST result in subclinical hypermetabolic ketosis, which can lead to reduced reproductive efficiency and a higher incidence of mastitis and other production related diseases. However, studies reviewed by Phipps (1989) provide no evidence for increased incidence of ketosis following bST treatment. Several of the studies of cows treated with bST in which milk yields were particularly high, report that the incidence of mastitis can increase. There are also some reports of increased incidence of lameness (Phipps loc. cit., Craven 1991). A general survey of mastitis incidence following bST use (Phipps loc. cit) makes it clear that there have been several studies in which bST use did not result in a greater likelihood of mastitis. However, high production levels are associated with greater incidence of both mastitis and lameness, and bST use can result in high production levels, so the discrepancies in research results in the effects of bST on mastitis may depend upon how great were the maximal production levels using bST. Increases in disease following bST use may be directly related to the metabolism associated with high production levels but welfare is obviously poorer if mastitis and lameness occur, whatever the exact reason for it.

Surveys of the results of several studies of bST-treated animals by Epstein (1990) and Epstein and Hardin (1990) showed that the conception rates of treated and control cows were 89.59% and 95.50%, respectively. Assuming that the attempts to get the cows to conceive were equivalent, these results also indicate poorer welfare in bST treated cows. Phipps (1989), in reviewing the evidence for effects of bST on reproduction, distinguished, firstly, between the use of bST early in lactation and late in lactation, and secondly, between higher and lower doses of bST. If the bST is administered early in lactation and at higher dose levels, the reductions in pregnancy rate reported by Epstein (1990) can be produced. However, it seems that administration of lower dose levels of bST later in lactation are less likely to have any adverse effects on welfare.

A further point, which may be very important to the cows, is that each injection has some effect on a cow and repeated injections may cause swollen and tender injection sites (Comstock, 1988). More general effects of bST use are: first, that higher mastitis incidence may result in more antibiotic treatment and greater risk of the development of pathogen resistance; and second, that the possible change from smaller to larger dairy farms, which could result from widespread bST usage could lead to poorer average stockmanship and less individual care of cows.

The one clear, but very important, study of the effects of pST on pig welfare shows that lameness is greatly increased in fast growing pST-treated animals (Simonsen, 1993).

Conclusions

The methodology for assessing animal welfare has developed rapidly in recent years. It has become clear that the welfare is better in some housing systems and using some management methods than others. Some of the areas where improvement is needed in existing systems are also apparent. Efforts to improve economic efficiency on farms have sometimes led to poorer welfare and it is clear that there is a greater risk of poor welfare if individual animals are required to perform at high feed conversion efficiency. Some breeding programmes have also led to welfare problems. It is clear from various fragments of evidence that systematic, comprehensive studies of welfare are necessary in all developments involving the production of transgenic animals or the use of new treatments like those made possible by recombinant DNA technology. There may be adverse effects on the welfare of the animals which would not have occurred if the new technology had not been used, for example the consequences of painful deformities. There may also be an increased chance that adverse effects of management as practised at present will continue instead of being reduced, for example disease associated with high production rates in cows. On the other hand, it may be that the welfare of animals will be improved as a consequence of the new procedure, for example if disease resistance is increased. There is much public concern over these matters and it is vital for the agricultural industry to be seen to have concern for the animals that are used. Most people consider that it is morally wrong for new technology to be applied to animals for commercial benefit if the welfare of the animal is poorer as a consequence.

The studies of the welfare of animals which are needed in order to appreciate all of the possible effects are described in this chapter. Thorough studies are needed because limited measurement may fail to detect all of the different attempts to cope with difficulties or all of the consequences of failure to cope. Prolonged studies are necessary because effects of substance administration may appear later in life and effects of genetic manipulation may appear at any stage in the life of an individual or may not be apparent until the next generation. Hence, there should be laws governing the commercial use of these procedures. In many countries, the scientific experimentation is adequately covered, so new laws need refer only to the application of the results of the experimentation. Existing laws on cruelty to animals or the welfare of farm animals do not adequately cover the problems. New laws are required to ensure that neither the use of recombinant DNA products nor the keeping of transgenic animals is permitted on commercial farms until it is clear that the welfare of these animals is not adversely affected in comparison with that of control animals. In principle, the new developments could have good or bad effects on animal welfare, but they should not be licensed for public use until the facts about such effects have been ascertained.

References

Agger, J.F. (1983) Production disease and mortality in dairy cows. Analysis of records from disposal plants from 1969–1982. In *Proceedings of the 5th International Conference on Production Diseases in Farm Animals*. pp. 308–311. Uppsala

Beilharz, R.G. (1985) Special phenomena. In *World Animal Science A5. Ethology of Farm Animals*. pp. 363–370 Edited by A.F. Fraser. Amsterdam: Elsevier

Broom, D.M. (1986) Indicators of poor welfare. British Veterinary Journal, **142**, 524–526

Broom, D.M. (1987) Applications of neurobiological studies to farm animal welfare. In *Biology of Stress in Farm Animals: an Integrated Approach*. Edited by P. R. Wiepkema and P.W.M. van Adrichem. Current Topics in Veterinary Medicine and Animal Science, **42**, 101–110. Dordrecht: Martinus Nijhoff

Broom, D.M. (1988) The scientific assessment of animal welfare. *Applied Animal Behaioural Science*, **20**, 5–19

Broom, D.M. (1991a) Animal welfare: concepts and measurement. *Journal of Animal Science*, **69**, 4167–4175

Broom, D.M. (1991b) Assessing welfare and suffering. *Behavioural Processes*, **25**, 117–123

Broom, D.M. (1993a) A usable definition of animal welfare. *Journal of Agricultural and Environmental Ethics*, **6** suppl 2, 15–25

Broom, D.M. (1993b) Assessing the welfare of modified or treated animals. *Livestock Production Science*, **36**, 39–54

Broom, D.M. (1994) The effects of production efficiency on animal welfare. In *Biological Basis of Sustainable Animal Production*. Edited by E.A. Huisman, J.W.M. Osse, D van der Heide, S.Tamminga, B.C. Tolkamp, W.P.E. Schouten, C.E. Hollingsworth and G. van Winkel. Wageningen : Pudoc pp. 201–210

Broom, D.M. and Johnson, K.G. (1993) *Stress and Animal Welfare*. London : Chapman and Hall

Coe, C.L., Lubach, G.R., Ershler, W.B. and Klopp, R.G. (1989) Influence of early rearing on lymphocyte proliferation responses in juvenile rhesus monkeys. *Brain, Behaviour and Immunity*, **3**, 47–60

Comstock, G. (1988) The case against bGH. *Agriculture and Human Values*, **5**, 36–52

Cooper, T.R., Trunkfield, H.R., Zanella, A.J. and Booth, W.D. (1989) An enzyme-linked immunosorbent assay (ELISA) for cortisol in the saliva of man and domestic farm animals. *Journal of Endocrinology*, **123**, R13–R16

Craven, N. (1991) Milk production and mastitis susceptibility: genetic relationships and influence of bovine somatotropin treatment. In *Mammites des Vaches Laitières*. pp. 55–59 Edited by J. Espinasse. Toulouse: Polygone

Cronin, G.M., Wiepkema, P.R. and van Ree, J.M. (1985) Endogenous opioids are involved in abnormal stereotyped behaviours of tethered sows. *Neuropeptides*, **6**, 527–530

Dämmrich, K. (1987) Organ change and damage during stress – morphological diagnosis. In *Biology of Stress in Farm Animals: an Integrated Approach*. pp 71–81 Edited by P.R. Wiepkema and P.W.M. van Adrichem. Dordrecht : Martinus Nijhoff

Dantzer, R., Mormède, P., Bluthé, R-M, and Soissons, J. (1983). The effect of different housing conditions on behavioural and adrenocortical reactions in veal calves. *Reproduction. Nutrition. Développement*, **23**, 67–74

Dawkins, M. (1983) Battery hens name their price : consumer demand theory and the measurement of animal needs. *Animal Behaviour*, **31**, 1195–1205

Dawkins, M. (1990) From an animal's point of view : motivation, fitness and animal welfare. *Behavioural and Brain Science*, **13**, 1–61

Duncan, I.J.H. (1987) The welfare of farm animals: An ethological approach. *Science Progress*, **71**, 317

Duncan, I.J.H. and Kite, V.G. (1987) Some investigations into motivation in the domestic fowl. *Applied Animal Behaviour Science*, **18**, 387–388

Ekesbo, I. (1981) Some aspects of sow health and housing. In *Welfare of Pigs*. Edited by W. Sybesma, Current Topics in Veterinary Medicine and Animal Science, **11**, 250–266. The Hague : Martinus Nijhoff

Epstein, S.S. (1990) Potential public health hazards of biosynthetic milk hormones. *International Journal of Health Services*, **20**, 73–84

Epstein, S.S., and Hardin, P. (1990) Confidential Monsanto research files dispute many bGH safety claims. *The Milkweed*, **128**, 3–6

Fraser, A.F., and Broom, D.M. (1990) *Farm Animal Behaviour and Welfare*. London : Baillière Tindall

Friend T.H., Polan, C.E., Gwazdauskas, F.C. and Heald, C.W. (1977) Adrenal glucocorticoid response to exogenous adrenocorticotropin mediated by density and social disruption in lactating cows. *Journal of Dairy Science*, **60**, 1958–1963

Gross, W.B., and Siegel, P.B. (1981) Long-term exposure of chickens to three levels of social stress. *Avian Diseases*, **25**, 312–325

Houpt, K.A. (1984 Treatment of aggression in horses. *Equine Practice*, **6**(6), 8–10

Hughes, J. , Smith. T.W., Kosterlitz. H.W., Fothergill, L.A., Morgan, B.A. and Morris, H.R. (1975) Identification of two related pentapeptides from the brain with potent opiate agonist activity. *Nature. London*, **258**, 577–579

Hurnik, J.F. and Lehman. H. (1988) Ethics and farm animal welfare. *Journal of Agricultural Ethics*, **1**, 305–318

Jeppesen, L.L. and Heller, K.E. (1986) Stress effects on circulating eosinophil leukocytes, breeding performance and reproductive success of ranch mink. *Scientifur*, **10**, 15–18

Juskevich, J.C., and Guyer, C.G. (1990) Bovine growth hormone: human food safety evaluation. *Science*, NY, **249**, 875–884

Kelley, K.W., (1985) Immunological consequences of changing environmental stimuli. In *Animal Stress*. Edited by G.P. Moberg, pp. 193–223. American Physiological Association

Kelley, K.W., R.E. Greenfield and J.F. Evermann (1982). Delayed-type hypersensitivity, contact sensitivity, and phytohemagglutinin skin-test responses of heat and cold-stressed calves. *American Journal of Veterinary Research*, **43**, 775–779

Koolhaas, J.M., Fokkema, D.S., Bohus, B. and van Oortmersson, G.A. (1986) Individual differentiation in blood pressure reactivity and behaviour of male rats. In '*Biobehavioural Bases of Coronary Heart Disease Vol.3*. pp. 517–526 Edited by T.M. Dembroski, T.H. Schmidt and G. Blümchen. Basel: Karger

Knowles, T.G. and Broom, D.M., (1990) Limb bone strength and movement in laying hens from different housing systems. *Veterinary Record*, **126**, 354–356

Kronfeld, D.S. (1988) Biologic and economic risks associated with use of bovine somatotropin. *Journal, American Veterinary Medical Association*, **1921**, 1693–1696

Ladewig, J. and Smidt, D. (1989) Behaviour, episodic secretion of cortisol and adrenocortical reactivity of bulls subjected to tethering. *Hormones and Behaviour*, **23**, 344–360

Mendl, M. (1990) Developmental experience and the potential for suffering : does 'out of experience' mean 'out of mind'? *Behavioural and Brain Sciences*, **13**, 28

Mendl, M., Broom, D.M. and Zanella, A.J. (1991) Adrenal cortex activity, reproduction and welfare of pregnant gilts in a group housing system. *Animal Production*, **52**, 578

Mendl, M., Zanella, A.J. and Broom, D.M. (1992a) The dexamethasone suppression test: an indicator of depression and poor welfare in sows. *Journal of Animal Science,* **70**, (Suppl. 1), 155

Mendl, M., Zanella, A.J. and Broom, D.M. (1992b) Physiological and reproductive correlates of behavioural strategies in female domestic pigs. *Animal Behaviour,* **44**, 1107–1121

Mepham, T.B. (1991) Bovine somatotrophin and public health. *British Medical Journal,* **302**, 483–484

Metz, J.H.M. and Oosterlee, C.C. (1981) Immunologische und ethologische Kriterien für die artgemassehaltung von Sauen und Ferkeln, *Actuelle Arbeiten zur artgemassen Tierhaltung KTBL Schrift*, **264**, 39–50. Darmstadt: KTBL

Meunier-Salaun, M.C., Vantrimponte, M.N., Raab, A. and Dantzer, R. (1987) Effect of floor area restriction upon performance, behaviour and physiology of growing-finishing pigs. *Journal of Animal Science,* **64**, 1371–1377

Norgaard-Nielsen, G. (1990) Bone strength of laying hens kept in an alternative system, compared with hens in cages and on deep litter. *British Poultry Science,* **31**, 81–89

Phipps, R.H. (1989) A review of the influence of somatotropin on health, reproduction and welfare in dairy cows. In *Use of Somatatropin in Livestock Production*. pp. 88–119 Edited by K. Sejrsen, M. Vestergaard and A. Neimann-Sorensen. London: Elsevier

Price, E.O. (1985) Sexual behaviour of large domestic farm animals: an overview. *Journal of Animal Science,* **61**, (Suppl. 3), 62

Prosser, C.G., Fleet, I.R. and Corps, A.N. (1989 Increased secretion of insulin-like growth factor I into milk of cows treated with recombinantly derived bovine growth hormone. *Journal of Dairy Research,* **56**, 17–26

Prosser, C.G and Mepham, T.B. (1989) Mechanism of action of bovine somatotropin in increasing milk yield in dairy ruminants. In *Use of somatotropin in Livestock Production*. pp. 1–17 Edited by K.Sejrsen, M. Vestergaard and A, Neimann-Sorensen. London: Elsevier

Prosser, C.G., Royle, C., Fleet, I.R. and Mepham, T.B. (1991) The galactopoietic effect of bovine growth hormone in goats is associated with increased concentrations of insulin-like growth factor-I in milk and mammary tissue. *Journal of Endocrinology,* **128**, 457–463

Pursel, V.G., Pinkert, C.A., Miller, K.F., Bott, D.J., Campbell, R.G., Palmiter, R.D., Brinster, R.L. and Hammer, R.E. (1989) Genetic engineering of livestock. *Science, NY*, **244**, 1281–1288

Restrepo, C. and Armario, A. (1987) Chronic stress alters pituitary-adrenal function of prepubertal male rats. *Psychoneuroendocrinology*, **12**, 393–398

Rushen, J. (1986) Aversion of sheep for handling treatments: paired choice experiments. *Applied Animal Behaviour Science,* **16**, 363–370

Shutt, D.A., Fell, L.R., Cornell, R., Bell, A.K., Wallace, C.A. and Smith, A.I. (1987) Stress-induced changes in plasma concentrations of immunoreactive β-endorphin and cortisol in response to routine surgical procedures in lambs. *Australian Journal of Biological Sciences*, **40**, 97–103

Simonsen, H.B. (1993) pST treatment and leg disorders in growing swine. *Livestock Production Sciences*, **36**, 67–70

Taylor, P.M. (1987) *Some Aspects of the Stress Response to Anaesthesia and Surgery in the Horse*. Ph.D. Thesis. University of Cambridge

Wal, P. van der, Niewhot, G.J. and Politlek, R.D. (Eds) (1989) *Biotechnology for Control of Growth and Produce Quality in Swine: Implications and Acceptability*. Wageningen: Pudoc

Wiepkema, P.R. and Schouten, W. (1992) Stereotypies in sows during chronic stress. *Psychotherapy and Psychosomatics*, **57**, 194–199

Willeberg, P. (1993) Bovine somatotrophin and clinical mastitis: epidemiological assessment of animal welfare risk. *Livestock Production Science*, **36**, 655–667

Zanella, A.J., Broom, D.M. and Mendl, M.T. (1991a) Responses to housing conditions and immunological state in sows. *Animal Production*, **52**, 579

Zanella, A.J., Broom, D.M. and Hunter, J.C. (1991b) Changes in opioid receptors of sows in relation to housing, inactivity and stereotypies. In *Applied Animal Behaviour: Past, Present and Future*. pp. 140–141 Edited by M.C. Appleby, R.I. Horrell, J.C. Petherick and S.M. Rutter. Potters Bar : Universities Federation for Animal Welfare