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Review Article

A review of animal welfare measurement in pigs

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ABSTRACT

In order to design housing and management systems which result in good welfare, the needs of the pigs must be investigated. One way to do this is to assess the strengths of positive and negative preferences in pigs. How much effort will pigs put into particular activities or the achieving of particular objectives and how hard will they work to avoid certain kinds of stimulation? Are there direct signs of good welfare? New housing systems can be compared with existing or obviously inadequate systems using indicators of poor welfare. These include abnormalities of behaviour, evidence of use of emergency physiological and behavioural responses, indications that brain mechanisms directed towards coping with difficulty are in use, immunosuppression, increased disease incidence, injury, suppression of growth or reproduction, and increased mortality rate. If a housing system results in difficulties in coping or failure to cope, as evidenced by such measures, then it is clear that the needs of the animal are not being met and welfare is poor. Since the indicators of welfare are quantifiable, the extent to which welfare is poor can be measured. The indicators of poor welfare and of good welfare provide some information about the extent of good feelings or of pain, fear, distress and other suffering. Such feelings are part of the biological functioning of animals and the controlling systems have evolved just as anatomy, physiology and the control of behaviour have evolved.

INTRODUCTION

When designing housing and management systems which will result in good pig welfare it is useful to assess the positive and negative preferences of pigs. When assessing a particular system or comparing systems, a wide range of indicators of poor welfare should be used. Both kinds of study give information about the needs of pigs. Welfare of an animal is its state as regards its attempts to cope with its environment (Broom, 1986) and both the concept and methods of assessing welfare are described in greater detail by Broom and Johnson (1993).

Indicators of welfare are summarised in Table 1 which includes measures providing information about how good and how poor welfare is. The remainder of this paper is concerned with the assessment of welfare over long periods so the measures described are appropriate for comparisons of housing and management systems. Some of these measures are also appropriate for evaluation of welfare during short-term problems such as those which may be associated with handling, transport, farm operations, markets, emergency situations such as fires or slaughter, but other welfare indicators can also be used at these times.

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TIME AND ENERGY ALLOCATION IN RICH ENVIRONMENTS

In attempts to understand how pigs assess various aspects of their environments, studies of animal preferences have been carried out. The simplest of such studies involves observing pigs in a rich environment and measuring their time budgets, i.e. how they allocate their time and energy to each of the possible activities which they can carry out. An indication of the importance of particular activities is obtained by how much time the animals spend carrying out the activities. Stolba and Wood-Gush (Stolba, 1982; Stolba and Wood-Gush, 1989) developed a "pig park" which consisted of an enclosure with fields, forest and a shrubbery area. The pigs were given the amount of food which they would have received in commercial housing. Family groups of pigs were observed and their behavioural repertoire was found to consist of 103 separate categories. The pigs spent 31% of daylight hours grazing, 21% rooting, 14% in locomotion and 6% lying. These figures are very different from those obtained from observation of confined pigs. Some activities are clearly associated with exploration of the environment (Wood-Gush and Vestergaard, 1989). A large amount of time allocation suggests that the behaviour is important to the pig but some infrequent behaviours may also be important. As a result of this research, Stolba and Wood-Gush designed a pig housing system, the family pen system, which provided for the needs of the pigs. Another

Table 1. Indicators of welfare reducing from good to poor.

Variety of normal behaviours shown.	good
Extent to which strongly preferred behaviours can be shown.	↓
Physiological indicators of pleasure.	↓
Behavioural indicators of pleasure.	↓
Reduced life expectancy.	↓
Reduced ability to grow or breed.	↓
Extent of body damage.	↓
Extent of disease.	↓
Extent of immunosuppression.	↓
Physiological attempts to cope.	↓
Behavioural attempts to cope.	↓
Extent of behaviour pathology.	↓
Brain changes, e.g. those indicating increased endogenous opioid usage.	↓
Extent of behavioural aversion shown.	↓
Extent to which normal physiological processes and anatomical development are prevented.	poor

(modified after Broom and Johnson, 1993)

study of pigs in fields and woodland in which 60 farrowings were observed by Jensen (1989) provided information about the sites chosen by pre-parturient sows and demonstrated that a substantial nest was usually built. Such information helps in the design of pig housing systems.

EXPERIMENTAL STUDIES OF PIG PREFERENCES

Pigs can reveal their preferences in a variety of ways, one of the easiest to assess being approaching and spending longer time at preferred rather than less-preferred aspects of their environment. Marx and Schuster (1980, 1982, 1984) gave piglets the choice of pens with different floors and found that they lay for longest on perforated plastic, with concrete and especially wire mesh floors less preferred. Similarly they spent more time in a pen with a container of straw than in pens without straw. In each of these studies the pigs had to allocate a small amount of time and energy in order to exhibit the preference but it is not clear how important the resource was to the animal.

Assessment of the importance of pig preferences involves making the animal work for a resource, expending energy in a quantifiable way, or to have to give up one resource of known importance in order to obtain the resource under investigation. In an investigation of substratum preferences in gilts, Van Rooijen (1980, 1981) found that preferences for an earth floor over a concrete floor were sufficient to overcome the normal preference for lying in a pen adjacent to that occupied by another gilt but preferences for straw bedding over wood shaving bedding were not sufficient to do so.

The fact that pigs perform an operant, such as pressing a panel or putting their nose in a slot, in order to change the ambient temperature or light level (Baldwin, 1979; Baldwin and Start, 1985), has made it possible to establish the physical conditions preferred by the pigs (Curtis, 1983). When animals will perform an operant in order to obtain a reinforcement like heating or access to a companion, it is possible to withhold the reinforcement until the operant procedure is performed several or many times. Pigs have been found to be willing to press a plate or lift a lever more than 50 times in order to get food, to gain access to earth for rooting, or on the day before farrowing to enter a pen containing straw (Hutson, 1989, 1992; Arey, 1992). When the operant must be carried out more than once in order to obtain the reinforcement, the number of performances of the operant for each reinforcement is the "fixed ratio". As this fixed ratio is increased, the number of times that the reinforcer is received may decline or remain about the same. In the case where the animal works harder and harder for the same frequency of reinforcement, it is said to have an inelastic demand for the resource. If, on the other hand, the frequency of reinforcement declines as the fixed ratio increases, the animal is said to have an elastic demand for the resource (Ladewig and Matthews, 1990; Matthews and Ladewig, 1994). These authors were able to discover that demand for food is relatively inelastic in pigs, but demand for locomotion is much more elastic. The use of such sophisticated techniques gives good quantitative data about the strength of animal preferences.

When good data about animal preferences and their strength have been obtained, they must still be interpreted with some care because animals may choose things which are bad for them. For example, individuals might choose to inject themselves with opioid drugs or to eat too much sweet food. However, in most cases where pigs show a strong preference for a resource, their welfare will be poor if they are deprived of the resource.

Future work on pig welfare should include attempts to find measurable variables which will indicate directly that welfare of the animal is good. At present any such measures of behaviour, physiology or brain function are not fully validated.

DIRECT MEASURES OF POOR WELFARE

Poor welfare may be short term or long term. Measures of short-term problems for pigs are summarised by Broom (1996) and Lambooij *et al.* (1996) in relation to welfare of pigs during transport. The measures described in the present paper concern longer term problems such as those which are caused by inadequate housing conditions. Such measures of poor welfare include those which indicate some reduction in the fitness of the individual, such as increased mortality levels, failure to grow normally or impaired reproduction, and those which quantify the difficulty which the individual has in coping with adversity.

Fitness measures

Farm animals have been selected for good reproductive performance for many generations and commonly maintain normal reproductive rates even under relatively difficult conditions. However, in comparisons of welfare in different housing and management conditions, reproductive output can still be a useful indicator that welfare is poor. Those sows which are less well able to breed or which produce fewer piglets because of environmental effects, have poorer welfare than sows which produce piglets normally.

Failure to gain weight or reduced weight gain are also indicators of poor welfare in young pigs. Piglets separated from their mothers before the natural weaning age of 9–16 weeks frequently show a growth check which indicates that welfare is poorer at that time. Social mixing of pigs at any age will often lead to an increased incidence of fighting, a reduction in food intake and a growth check, so here also poorer welfare is indicated. Those animals within a group which fail to grow, or grow slowly, will be the individuals which are less well able to cope with the environmental conditions so have poorer welfare than the group members which grow normally.

If the life expectancy of a pig in one housing condition was four years, but in another housing condition, such a pig might live for ten years, we could conclude that welfare of pigs is better in the second condition. In practice, the data

which can be collected normally concerns early mortality but if pigs are left to complete their life, rather than being slaughtered early, then life expectancy would be used in any comparison of housing conditions.

Physiological measures

Measurements of heart rate, adrenal medullary hormones and adrenal cortex hormones are more appropriate for the assessment of short-term problems than for the assessment of welfare of pigs in different housing conditions. However, frequent measurement of cortisol and corticosterone in catheterized pigs can give useful information about responses to housing conditions. A test of adrenal function which indicates how much the adrenal cortex response has been used by the pig in the preceding period is generally of more use in welfare assessment. One study of this type was that of Meunier Salaun *et al.* (1987) who found that pigs kept at higher stocking densities had higher cortisol responses to adrenocorticotrophic hormone (ACTH) challenge. Similarly, group-housed sows which lost most aggressive encounters showed greater responses to a standard ACTH dose and greater baseline cortisol levels than sows which won most of their aggressive encounters or those which submissively avoided encounters (Mendl *et al.*, 1992). Where the effects on pigs of two environmental situations are compared, a higher cortisol response to ACTH challenge indicates that the individuals concerned have used their adrenal cortex more but we do not yet know over what time scale. Absence of increase in response to ACTH challenge in both groups of animals studied does not mean that the animals have not had to use their adrenal cortex response, since the period of increased use may be too long before the ACTH challenge test. Another possibility is that welfare differs in the two groups but the response to the adverse conditions does not include an adrenal cortex response.

Another physiological response to adversity which can be detected and which may eventually prove to be a useful welfare measure is the production of opioids. When ACTH is produced by the hypothalamic-pituitary-adrenal cortex axis, the opioid ß-endorphin is usually produced as well and its concentration in blood plasma can be measured. This plasma ß-endorphin has peripheral effects but opioids such as ß-endorphin, dynorphin and the enkephalins have effects in the brain, some of which involve analgesia and may help in coping with adversity. In pigs the density of opioid receptors in the brain has been shown to be related to levels of stereotypies (Zanella *et al.*, 1991, 1996).

Immunological responses

In some circumstances, increased adrenocortical activity results in immunosuppression. Hence immunosuppression can indicate the substantial use of adrenal responses to a difficult environment. However, immunosuppression can also be caused by changes in the animal which involve no adrenal responses. Measures of immunosuppression include simple measures of white cell numbers, which generally provide only a limited amount of information, measures of antibody response to antigen challenge, and measures of T-lymphocyte function. An example of the effects of housing conditions on antibody production capabilities is the work of Barnett *et al.* (1987 a,b) who found that immunoglobulin levels (IgB and IgM), after challenge with *Escherischia coli* K99, were lower in tethered sows than in group-housed sows. The relationship between adrenal activity and antibody production potential was shown in a study by Zanella (Zanella *et al.*, 1991; Broom and Johnson, 1993). Sows which showed a large cortisol response to challenge with ACTH, also showed lower antibody production after challenge with the tetanus toxoid antigen.

The T-lymphocyte function studies which can provide useful information about welfare of the animals are varied but largely untested for pigs. Skin thickening responses following application of substances such as 2,4-dinitro-1-fluorobenzene, or phytohaemagglutinin, is mediated by T-lymphocytes. Immunosuppressed animals should show a reduced response, as they should in tests using mitogens such as concanavalin A to indicate the magnitude of lymphocyte proliferation *in vitro*. Other tests involving the measurement of T-cell activity are those in which the activity of natural killer cells is measured or those where amounts of interleukin production are assessed.

Disease incidence and injury measures

Wherever pigs are diseased or injured their welfare is less good than that of healthy pigs. Indeed health is an important part of welfare and poor health always means poor welfare. However, there is a large difference between welfare of animals which are severely affected and slightly affected by pathogen attack and some injuries have a much worse effect on pigs than others. Hence, just as with all other welfare indicators, a range of effects of different magnitude can exist and careful evaluation of disease and injury effects is necessary when welfare of pigs in different housing and management systems is being compared.

Behaviour measures as welfare indicators

The best indicators of long-term problems for pigs are frequent measurements of abnormalities of behaviour. One kind of measurement is that of movement difficulties. If pigs cannot carry out normal movements, for example lying behaviour (Marchant and Broom, 1996), their welfare is poorer than that of pigs which can carry out these movements. The most widely recorded abnormalities of behaviour are stereotypies, excessive aggressive behaviour and substantially reduced responsiveness to stimuli which would normally elicit a response. A stereotypy is a repeated and relatively invariant sequence of movements which has no obvious function (Ödberg, 1978; Broom, 1983; Broom and Johnson, 1993). Pigs which show stereotypies certainly have some problem, whatever the function of the stereotypy, so if high levels of stereotypies are recorded then welfare is poor. Other behavioural abnormalities, such as tail-biting, belly-nosing and most excessive aggression, also indicate that welfare of the animal which carries out the behaviour is poor. Welfare of the recipient may also be poor. Apathy and unresponsiveness are well-known behavioural abnormalities in pigs (Van Putten, 1980; Wiepkema *et al.*, 1983; Broom, 1987). As in man, they are probably signs of depression and may be associated with some of the same brain pharmacology changes in both species.

It is important to distinguish between normal and abnormal behaviour in welfare assessment. A pig which is chewing straw or a small branch is showing normal behaviour but a pig which is showing a stereotypy such as sham-chewing, bar-biting or drinker pressing is abnormal in its behaviour. There are parallels in human behaviour for people who are autistic or who are kept in solitary confinement for long periods and may show prolonged rocking or head-weaving movements, or walking repeated routes on the cell floor, which are immediately recognised as abnormal by an observer and taken to indicate poor welfare in the individuals. Normal people may use the same groups of muscles as those used in the rocking or head-weaving movements or may walk in non-stereotyped ways without any suggestion that their welfare is poor. It is important to describe the behaviour carefully where a behavioural abnormality is suspected. Some repeated movements by pigs, such as stone-chewing by sows, have still to be examined experimentally to determine whether or not the behaviour should be characterised as a stereotypy and hence as an indicator of poor welfare.

Combining welfare measures in assessment

Since there are various methods for coping with their environment which animals use and various consequences of failure to cope with adversity in life it is important that a

range of measurements be used in the assessment of welfare. One individual might show an adrenal response when trying to cope with adverse conditions whereas another might show a behavioural response which would be recognised as abnormal by an animal welfare scientist. Hence, it is very important that a range of measures should be used in any attempt to compare welfare of individual animals kept in different ways. Each measure is of value and the absence of an indication using one measure does not mean that there is no problem.

An example of a study in which a range of welfare measures was used is that described below concerning the assessment of welfare in dry sows.

WELFARE OF DRY SOWS IN DIFFERENT HOUSING CONDITIONS

Welfare of pigs housed in various types of dry sow accommodation has been compared in a number of experimental studies. In most of these, pigs housed in stalls or tethers have been compared with those housed in small groups of between two and ten (e.g. Vestergaard and Hansen, 1984; Von Borell and Ladewig, 1989). In some of these studies, the pigs were not pregnant (e.g. Barnett *et al.*, 1984), and in many the subjects were animals in their first pregnancy (e.g. Barnett *et al.*, 1985, 1987a; Arrelano *et al.*, 1992; Rampacek *et al.*, 1984). By focusing on gilts, most of these studies have provided information about the animals' initial responses to the housing conditions, but there are fewer data relating to the long-term effects of housing systems on sow welfare.

A study by Broom *et al.* (1995) was designed to start to fill this gap in our knowledge by following pigs from early life until their fourth pregnancy in three different housing systems. In addition, the study allowed a long-term evaluation of the consequences for welfare of the electronic sow feeder system, a group-housing system which is growing in importance in several countries (Edwards and Riley, 1986; Hunter *et al.*, 1988; Mendl *et al.*, 1992). This system usually accommodates considerably more sows than the group-housing systems studied in previous research, so it is important to examine how well sows are able to cope with these larger group sizes.

Sows housed in an electronic sow feeder system were compared with those housed in groups of five with access to individual feeders, and to those housed in conventional gestation stalls. All three systems were newly built to high quality commercial specifications, adjacent to each other in identical sections of a building. All pigs were fed the same diet and looked after by the same stockmen in order to minimise the effects that food and stockmanship may exert on the responses of pigs to husbandry and housing conditions (Hemsworth *et al.*, 1989; Rushen and De Passillé, 1992).

A longitudinal experimental design was used to obtain information on how the pigs responded to their initial introduction to the three housing systems (during the first pregnancy), and how they adjusted to the systems over time. A variety of measures, which can be used as indicators of animal welfare (Broom, 1988; Broom and Johnson, 1993), were used during the first and fourth pregnancies. These included measures of stereotypies, aggression, responsiveness, pituitary-adrenal function, immune system function, growth rate and reproductive success.

In this comparison, the sows grew to a smaller final size in the stalls but there were no differences in reproductive output, in responses to ACTH challenge or in the single test of antibody production in response to antigen challenge which was carried out. Several measures suggested that stall-housed animals found the conditions more difficult than those housed in groups. During both first and fourth pregnancies, they spent much more time performing stereotypies than group-housed animals. In the fourth pregnancy the stall-housed sows spent a mean of 14% of time on obvious stereotypies, plus >10% "drinking" and >20% rooting or chewing at pen fittings. The total times, expressed as percentages of observation time, spent on all of these largely stereotyped activities were 50.14±9.22% for stall-housed sows, 8.19±1.79% for sows in small groups and 3.69±0.7% for sows with an electronic feeder. Although there is still debate as to the significance of stereotypies in welfare terms (Mason, 1991), a considerable body of evidence indicates that they often develop in situations where the animal is frustrated in that its needs cannot be fulfilled (Mason, 1991; Broom and Johnson, 1993). This would suggest that the stall-housed pigs encountered such frustrating situations more often than those housed in groups, due possibly to their inability to satisfy motivation to move, forage and express other forms of behaviour, and due to frustration caused by unresolved antagonistic encounters with neighbours. The animals in each of the conditions received the same concentrate diet and although some straw was eaten by group-housed animals and none by animals in stalls it is most unlikely that differences in food availability account for the large differences between stall- and group-housed animals in stereotypy incidence. In stalls there was a substantial increase in the duration of stereotypies between the first and the fourth parity. Stolba *et al.* (1983) and Cronin and Wiepkema (1984) also reported that the time spent performing stereotypies increased substantially with time spent in stalls.

Further evidence of problems for stall-housed sows comes from the fact that they experienced undecided antagonistic interactions up to three times as often as group-housed sows, were scarcely able to use active avoidance behaviour, and escalated antagonistic interactions most often. This was particularly evident in the fourth pregnancy. Barnett *et al.* (1987b) suggest that this apparent inability to resolve agonistic interactions is likely to be a cause of stress.

In a study by Marchant and Broom (1996) of the sows from stalls and from the large group, it was apparent that inability to exercise when living in stalls resulted in weaker muscles, weaker bones and more movement difficulties. Following slaughter, muscles and bones from fore- and hindlimbs of sows were weighed and bone strength was measured using a tensiometer. The muscle weight as a proportion of body weight was lower in eight important muscles in stall-housed sows compared with group-housed sows. The femur and humerus in stall-housed sows were 62% and 72% of the weight of those in group-housed sows. Stall-housed sows also took much longer to lie down and were less controlled in their lying than group-housed sows. An effect of lack of exercise on bone strength has not previously been reported for sows but has been described in man and hens. The sows did not break their leg bones but some extra risk of breakage and of lameness must result from the weakness in stall-housed sows. Lameness is known to be more frequent in confined sows than in those kept in groups.

The results of these studies confirm, using several indicators, that welfare is poorer in stall-housed sows than in group-housed sows. Equally, high levels of aggressive behaviour and bone weakness in stall-housed animals indicate greater difficulty in coping with the environment and hence poor welfare. Indeed a long list of research papers show effects of stall-housing on sows which are sufficiently severe that many people would consider that such housing is unacceptable. There is no difference in the scientific evidence concerning the degree of poor welfare in stall-housed and tethered sows.

CONCLUSIONS

A wide range of measurements is now available for use in studies of pig welfare. Studies should be designed so as to use several measures, especially where direct indicators of poor welfare are used. This necessity is a consequence of the variability of coping methods used by individual pigs and the range of effects of the environment on animals which are failing to cope. The measures of the strength of preferences and the direct indicators of poor welfare provide some information about the feelings of the pigs. We should try to assess their feelings even if we cannot expect to know exactly what they are. However, in many cases we obtain good information about welfare, for example about extent of injury, disease or abnormal behaviour, without having any precise idea about feelings. The absence of precise conclusions about feelings does not mean that the data are not useful in welfare assessment since we are concerned with all aspects of attempts to cope with the environment and feelings are just a part of these attempts. Feelings are biological mechanisms which, like other mechanisms, have evolved because they are beneficial to individual animals. In assessing pig welfare we should use all of the information available about pig biology so that the range of measurements used can be interpreted and the results of the different kinds of assessment can be balanced in coming to a conclusion about housing and management systems.

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