Doc XXIV/B3/ScVC/0005/1997
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THE WELFARE OF INTENSIVELY KEPT PIGS

Report of the Scientific Veterinary Committee

Adopted 30 September 1997

PREFACE

Council Directive 91/630/EEC lays down minimum standards for the protection of pigs. Article 6 of that Directive states:

The Commission wasrequested to submit a report to the Council by 1 October 1997, drawn up on the basis of an opinion from the Scientific Veterinary Committee, on the intensive pig-rearing system(s) which comply with the welfare requirements of pigs from the pathological, zootechnical, physiological and behavioural points of view and on the socio-economic implications of the different systems. The report shall particularly take into account the welfare of sows reared in varying degrees of confinement and in groups and shall be accompanied by appropriate proposals which take account of the conclusions of the report.

The Commission services requested the Scientific Veterinary Committee (Animal Welfare Section) to make such a report. The Committee was asked to examine in detail the welfare of pigs kept in intensive farming systems, and in particular the welfare of sows reared in varying degrees of confinement and in groups, as well as the socio-economic implications of different systems of rearing.

The Committee established an expert working group under the chairmanship of Professor P. Jensen. The members of this group listed below were invited on the basis of their scientific expertise in the field and not as representatives of their country.

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The report which follows gathers together and presents the current scientific evidence regarding the welfare of pigs in various rearing systems. It was based on the work of the expert group and was adopted by the Scientific Veterinary Committee (Animal Welfare Section) on 30 September 1997.

Members of the Scientific Veterinary Committee, Animal Welfare Section

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CONTENTS

CHAPTER 1 INTRODUCTION: CONCEPTS AND MEASUREMENT OF WELFARE

1.1 Aims of report

There is much scientific literature concerning the welfare of pigs. In this report we review that literature with reference especially to housing systems, and management procedures which are directly related to housing, feeding and the maintenance of good welfare including good health. Those points concerning environmental temperature and lighting, everyday care and inspection which are adequately covered in Directive 91/630/EEC are discussed only where additional information concerning welfare is available. The prevention and control of infectious disease, while of great importance for the welfare of pigs, has been discussed elsewhere, and will only be considered in the present report where it is pertinent to the comparison of different housing and management systems.

The structure of the report is as follows. In this first chapter the concepts of welfare and needs are introduced and there is a summary of methods of assessing the welfare of animals, in particular physiological, behavioural and health measurements. Chapter 2 summarises the biology and natural behaviour of pigs and in Chapter 3, the various pig production systems are described. Information about the range of husbandry factors which can affect pig welfare is presented in detail in Chapter 4. Comparisons of pig welfare in different systems are reviewed in Chapter 5 with each aspect of pig farming being considered separately but with interactions between the different aspects being considered. Chapter 6 is a description of the socio-economic consequences of some of the changes recommended in this report and includes the results of some original investigations. The final two chapters: 7 and 8, summarise recommendations for future research and the conclusions of this report. Finally, the substantial list of references quoted is appended.

1.2 Welfare

Animals can encounter a variety of difficulties during their lives and they use physiological and behavioural methods to try to cope with these. The extent to which coping methods are used can be measured, as can the consequences of failure to cope, for example reduced ability to grow or reproduce. The welfare of an individual is its state as regards its attempts to cope with its environment (Broom 1986). Welfare can vary from very poor to very good and some scientific and objective measurements of welfare can be made. The state of the animal, as referred to in the definition, includes the feelings of the individual animal as well as its health, physiological functioning and evidence of long term harm. Suffering is one of the most important aspects of poor welfare and we should investigate the existence of good or bad feelings wherever possible when trying to assess welfare (Dawkins 1990). Indeed some authors limit the term welfare to refer to feelings (Duncan and Petherick 1991) and others refer to positive and negative experiences (Simonsen 1996). However, most people have a wider view of welfare. Measurements which are relevant to the assessment of welfare include those of injury level, disease incidence, pain responses, the effects of fear and the behavioural and physiological consequences of lack of control, especially frustration. The links between coping difficulties, disease and injury are emphasised in Moberg's (1985) concept of pre-pathological state. For details of welfare assessment methods see Broom and Johnson (1993).

Situations or human actions which lead to poor welfare include: direct damage to the animal; neglect which is deliberate, accidental or due to lack of knowledge; incorrect or insufficient feeding; provision of inadequate conditions during housing, transport or marketing; disease; failure to provide for emergencies and improper procedures prior to and during slaughter. Direct damage includes hitting or frightening the animal and carrying out unnecessary surgical operations. Neglect might involve failure to feed or clean out adequately, to treat if diseased, or to care for if injured, or seriously disturbed or at risk. Emergencies which could arise on any animal unit are fire, power failure or extreme weather conditions. Welfare can be very poor in these emergency situations and provision should be made for early warning, back-up power supplies, preventing the freezing of water supplies, providing ventilation or showers in very hot conditions, fire prevention, fire-fighting, and rapid evacuation of all animals in case of fire. The welfare of most diseased animals is poor, sometimes very poor, so disease prevention, without general exacerbation of resistance in pathogenic organisms and associated disease problems by indiscriminate use of antibiotics, is desirable. Procedures which minimise pathogen contact with the animals, vaccination and the treatment of diseased individuals are the best strategy here. Conditions and procedures when animals are handled, transported, marketed and slaughtered can often lead to very poor welfare, but the topic which will be discussed in most detail in this report is the housing and associated management of pigs.

The factors affecting welfare which are outlined above fall into three, somewhat overlapping categories in terms of human responsibility. Firstly, the design of the housing and management system is largely the responsibility of the owner of the unit and the site manager with advice from system designers. These people have a substantial effect on the welfare of large numbers of individual animals. Secondly, the men and women who care directly for the animals by feeding them, cleaning up after them, checking them to see if they have problems, handling them for treatment or movement to another place, and loading them on to vehicles, have a very important effect on animal welfare. Thirdly, contributions are also made by specialists such as veterinary surgeons, vehicle drivers and abattoir staff. None of these three groups of people alone can ensure that welfare is good.

1.3 Needs

A need is a requirement, which is a consequence of the biology of the animal, to obtain a particular resource or respond to a particular environmental or bodily stimulus (see Broom and Johnson 1993). Needs are dictated by the basic biology of the animal for they relate to its various functional systems. The term "need" refers to requirements which are essential for survival and to requirements which are not necessarily essential for survival, at least in the short term, but which are of some significant importance to the animal. It is not used for those preferences which are of little importance to the animal. The term covers requirements which vary in importance and in the urgency with which they should be satisfied. An animal needs to rapidly avoid a falling tree, or it will die, and it needs to obtain sufficient food in order to survive. However it may survive for a very long time on a diet which lacks a nutrient and hence causes serious clinical disorders with associated distress so we would say that it needs a diet which includes that nutrient. Some needs exist at certain times of life only, for example the need of a parent animal to build a nest and care for the young, but the motivation to do this is very strong at that time. Hence survival is not the only criterion for deciding that something is a need. Indeed needs exist in the short term and an animal which has just ingested an adequate meal does not need food at all for some time. It is not useful to try to divide needs into essential and non-essential because different needs are paramount at different times and an individual may be willing to allocate all of its available resources to an objective which does not affect its survival chances. Scientific studies reveal how important requirements are by providing evidence of the consequences if they are not met or of the strength of the animals' positive or negative preferences.

Farm animals have an array of needs similar to those of their wild ancestors. The general mechanisms for controlling interactions with the individual's environment which evolved within the species are still present in our domestic animals, although some responses such as those associated with flight from man are reduced. Domestic pigs are changed from their ancestors in some ways, as discussed in Chapter 2, but in general functioning they have many similarities to them. Those systems used to control interactions with the environment operate by feed-forward control, in which action is taken before environmental changes affect the animal, as well as by negative feedback control. The ability to regulate body state is very important to individuals and inability to control interactions with the environment can cause serious problems. As a consequence, animals have elaborate motivational mechanisms which they use to respond to stimuli and to make physiological and behavioural changes appropriately. Some needs are simple, such as to escape the debilitating effects of low body temperature or high concentration of body fluids. Others are complex consequences of the mechanisms which promote survival and reproduction. For example, most animals need to carry out foraging behaviour as well as to actually obtain the food and hens or sows need to build a nest as well as to lay eggs or give birth in suitable temperature conditions. The animals show abnormalities of behaviour or physiology if they cannot do so (Broom and Johnson 1993). Various functions are described below (modified after Broom 1991) with explanations of the needs and what, first the young mammal and then the older animal must do in order to satisfy them.

1. In order to obtain adequate nutrients and to reduce disease incidence the young mammal must ingest and digest, first colostrum and then milk. The biological mechanisms which have evolved in order to achieve this are searching behaviour which should result in finding a teat and then the licking and sucking of a teat-like object.

2. The functions of recuperation and avoiding danger during the time of day when feeding is less efficient in range conditions are served by resting and sleeping. Adequate rest and sleep require that the animal adopts a sleeping posture on a suitable surface for a period during which there is not too much disturbance.

3. The avoidance of danger also requires that animals explore their surroundings so as to find out about sources of danger, and to hide or show escape responses if necessary. Exploration is also of value in the efficient exploitation of resources. The need to explore exists for all animals whilst those to hide or to escape exist if the animal perceives that there is some danger. Man often elicits responses typical of those to a dangerous predator by farm animals and many events in life elicit attempts to hide or escape.

4. In order that bone and muscle can develop normally and injury can be avoided the animal needs to take sufficient exercise and to move or adopt postures which do not cause discomfort. If bones are not loaded by muscle action and body movement then osteopAenia will develop. A small amount of exercise at frequent intervals may be sufficient to ensure normal bone development. Extreme inactivity causes very abnormal muscle development and may also cause joint problems. The biological mechanism to prevent or remedy these problems is for animals to want to take regular exercise and to avoid discomfort such as that which results from difficulty in making certain movements.

5. Important aspects of gut development are associated with strong preferences to eat certain types of food. Any inadequacies of nutrients also make the animals want to eat a variety of materials which might supply the missing nutrient.

6. Disease and parasitism result in poor welfare and animals have mechanisms for minimising them. One of them involves colostrum and other essential food ingestion and another involves keeping the body clean. Pigs attempt to localise dung in a small part of their environment.

7. In wild ungulates the mother is vitally important in increasing the survival chances of the young. Hence early behaviour and physiology is directed towards establishing a bond with the mother and obtaining from her: colostrum, milk, protection, and information about food, danger etc. If the young are separated from their mothers at a very early age, this separation causes some problems for them.

8. For social animals the ability to deal with social situations is important and demanding for them. In order to develop social ability each animal needs to approach and interact with conspecifics.

Whilst a general study of the biology of animals tells us that each of these needs is likely to be of importance to them, measurements of behaviour and physiology give more information about how important they are. Firstly, frequent and vigorous behaviour or attempted behaviour, such as sucking or grooming, indicates the magnitude of the need. Secondly, experimental studies of preferences are of value, especially if they include some means of assessing the strength of the preference. Thirdly, it may be impossible for animals in certain farm conditions to show some kinds of behaviour because of the restrictions placed upon them by those conditions, so abnormal anatomical development, behaviour or physiology may occur. As wide a range as possible of signs of poor welfare, (see Chapter 2) should be used to assess the importance of the needs. It is necessary to determine the effects on animals when their needs are not satisfied or are only partially satisfied.

1.4 Needs, freedoms and welfare

The approach which has been adopted in the introduction to this report is to explain the needs of animals and also the importance of considering these carefully so that they can be satisfied and the welfare of the animals will be good. A related approach is to state what freedom should be given to each animal. In this sense a freedom is a possibility to have self determination by carrying out an action or avoiding a problem. Lists of freedoms are a useful initial guideline for those practically involved with the care of animals, for example animals should have freedom from hunger, thirst, discomfort, pain, injury, disease, fear and distress and freedom to express normal behaviour. However it is seldom possible to provide any of these freedoms in their entirety and more detail is required about the exact needs of animals. Hence it is assumed in this report that general guidelines are available about the freedoms which should be provided, but the data presented about needs and the conclusions are based on information on the basic biology of the animals and on scientific studies of what results in good or poor welfare.

1.5 Introduction to welfare measurement

The major categories of indicators of how good or how poor the welfare of an animal is are behavioural, physiological, injuries, other aspects of health, growth, reproduction and life expectancy. Behavioural and physiological measures have been used for many years to evaluate the ability of domestic animals to cope in the systems in which they are reared (Wiepkema and van Adrichem 1987, Fraser and Broom 1990). Both types of measure are useful but care must be taken in data collection and in the interpretation of the results for the assessment of animal welfare (Barnett and Hemsworth 1990, Rushen 1991, Dantzer 1991, Rushen and de Passillé 1992, Mason and Mendl 1993). Welfare is poorer when there is an injury or a disease condition than when there is not but there is a range of effects from the trivial to the severe. If growth or reproduction are prevented or impaired, or if life expectancy is reduced, welfare is poorer than if there is no such effect. Whenever possible, when using all of these indicators, the feelings of the individual are assessed but all indicators of good or poor welfare should be used. There can be contradictory results and authors may differ in their interpretations. Examples will not be taken entirely from work on pigs as the intention is to illustrate the use of those indices which are of value in the assessment of pig welfare.

Since animals use a wide range of methods of trying to cope with adversity and there are various consequences when individuals are not coping, it is important that a wide range of indicators be used when assessing welfare. An individual which shows no clinical signs of disease and no behavioural abnormality may be showing physiological changes which indicate that it is having much difficulty coping with its environment so its welfare is poor. Another individual might grow well but be clearly abnormal in its behaviour so its welfare is poor. Hence we should attempt to recognise and measure any indicator of suffering or other aspects of poor welfare. It is also important when trying to design or improve pig housing and management systems, to attempt to ascertain what is important to the animal. Such investigations of the functioning of biological systems in the animal complement investigations in which good or poor welfare is recognised directly as described in the paragraphs above in attempts to determine the needs of animals.

1.6 Behavioural measurements

Changes in behaviour patterns are among the first readily detectable responses of an animal to perceived changes in its environment. Behaviour occurs as a consequence of the animal's motivational state and therefore the quantification of behaviour patterns is in fact a measure of motivation (Dellmeier 1989).

A wide variety of behavioural parameters have been used to assess welfare, and the validity of particular behavioural indices has been the subject of recent discussion (Barnett and Hemsworth 1990, Rushen and de Passillé 1992, Mason and Mendl 1993). The use of behavioural parameters for the assessment of welfare has been reviewed by Dantzer and Mormède (1979), Dawkins (1980), Duncan and Dawkins (1983) and Broom and Johnson (1993).

1.6.1 Preference tests

Preference tests present the animal with choices and are only capable of providing relative information about the welfare problems or benefits of the treatments tested. For example, they cannot indicate whether a particular housing design actually causes the animal stress or suffering (Rushen and de Passillé 1992). Moreover, the behavioural choices that an animal makes following brief exposure to a stimulus may be distinguished from its choices following prolonged exposure (Duncan 1978). However, preference tests are very useful when designed to answer a specific question as they enable the question to be put directly to the animal (Phillips *et al.* 1988, Farmer and Cristison 1982).

The strength of an animal's preferences and thus whether they can be said to constitute needs, can be assessed by monitoring the incidence of abnormal behaviour patterns and physiological indicators of stress when the animal's preference is denied. It is also possible to quantify the strength of preferences by measuring how hard the animal is prepared to work in order to have them met. These methods and indices for the assessment of the strength of an animal's motivation are described below.

1.6.2 Tests of aversion

Measurements of the animal's aversion to a stimulus are the most direct indices of short-term suffering (Rushen and de Passillé 1992), although it is not known whether they are of use in the assessment of chronic suffering owing to a lack of studies on this subject. They may therefore be of limited value in assessing the effect of housing systems upon welfare. Moreover, the results of aversion tests may be confounded by factors affecting memory or learning ability (Rushen 1990).

1.6.3 Behaviour deprivation and measures of motivation

Animals remain motivated to perform certain behaviours even if they are prevented from doing so by their physical environment. It is possible to identify behaviour patterns which the animal is highly motivated, but unable to perform, from the occurrence of abnormal behaviour patterns. For example, the animal may perform the motivated behaviour in an altered form or in an unusual context. The occurrence of apparently unrelated activities may also be indicative of behavioural frustration. Some of these activities are termed redirected behaviours because their performance, or the excessive degree to which they are performed, is a consequence of an inability to perform some other highly motivated behaviour pattern. The identity of the motivated behaviour pattern may not be clear from the morphology of redirected activities. However, it may be deduced by comparing the extent to which the redirected behaviours are performed in experimental environments which differ only in respect to their suitability for the expression of particular behaviour patterns.

An additional technique may be used to assess the strength of an animal's motivation to perform a particular behaviour pattern. The amount that an animal is prepared to "pay" for the opportunity to perform the behaviour can be measured in terms of its cost to the animal in energy or time expended (Dawkins 1990).

1.6.4 Abnormal behaviours

Abnormal behaviours are those which differ in pattern, frequency or context from those which are shown by most members of the species in conditions which allow a full range of behaviour (Broom and Johnson 1993). There can be abnormalities of feeding, grooming, sexual behaviour etc. One category of abnormal behaviour is the stereotypy. Stereotypies are repeated, relatively invariate sequences of movements which have no obvious purpose (Fraser and Broom 1990). A considerable amount of discussion is focused at present upon stereotypies and their causes, function and consequences for animal welfare. The many studies on this topic have been presented in reviews (Sambraus 1985, Dantzer 1986, Mason 1991) and books (Lawrence and Rushen 1993). Regardless of the function of stereotypies (as a coping mechanism or otherwise), their presence in an animal's behaviour helps to pinpoint the specific problems of the animal's environment for its welfare (Rushen and de Passillé 1992). Stereotypies develop when the animal is severely or chronically frustrated. Hence their development indicates that the animal is having difficulty in coping and its welfare is poor.

Other abnormal behaviours include those which are directly attributable to a physical restriction and those which are responses, perhaps as part of attempts to cope with problems. Confined animals may be unable to show certain movements or take longer to carry out movements, animals on slippery floors may slip or have to modify their lying movements and animals unable to suck the mother's teat may suck something else. Activity, the variety of behaviour shown and responsiveness to stimuli may be much lower in depressed individuals than in those which are not depressed. Social responses may be exaggerated or misdirected.

1.7 Physiological measurements

1.7.1 Hypothalamic-pituitary-adrenocortical activity

Although there is no single response which is common to all kinds of problems in life or all emergency reactions, the adrenal cortex response does occur in diverse difficult situations and is useful in welfare assessment. The function of cortisol or corticosterone (glucocorticoid) production is to provide extra energy for forthcoming activity. Hence production of these hormones can occur in situations which are not harmful to the individual as well as in situations which are potentially or actually harmful. Courtship behaviour, mating, active prey chasing or even nursing behaviour can be associated with glucocorticoid production (Walker *et al.* 1992, Broom and Johnson 1993). Because elevation of adrenal cortex hormones can sometimes indicate a substantial problem for the animal and on other occasions do not indicate poor welfare or the likelihood of stress, care must be taken in interpreting such hormone level elevations. In practice, however, it is usually quite obvious whether the conditions obtaining are useful to the individual or likely to be adverse for it. If cortisol levels increase when animals are, for example, hit, chased, forced to climb a steep loading ramp, or confined, there can be no doubt that this is a response to difficulty rather than a prelude to courtship, nursing or prey catching. If there is a larger increase in cortisol in one difficult condition than in another, then it may be concluded that the first condition is more taxing for the individual than the second. On all occasions when adrenal cortex measures are taken it is essential that other information about the animal, especially its behaviour, is obtained.

Other considerations when measurements of glucocorticoid levels in body fluids are made in order to assess animal welfare are: 1. the duration of the response; 2. the extent of daily fluctuations in normal adrenal cortex activity; 3. the variation in the magnitude of the response to different kinds of problems. Some of these problems in interpretation of adrenal cortex responses are discussed by Rushen (1991), Mason and Mendl (1993) and Broom and Johnson (1993).

1. When an animal is disturbed sufficiently by an event for an adrenal cortex response to occur, in most domestic animal species the elevation of glucocorticoid in the blood takes approximately two minutes to become evident. It then rises to a peak after 5 to 20 minutes and starts to decline after 15 to 40 minutes, the larger figures referring to more extreme responses. Further responses may occur subsequently. Hence the effects of short term experiences such as handling, or brief transport can be assessed readily by measuring the magnitude of the glucocorticoid increase in blood, saliva or, after a longer time lag, urine.

Housing conditions may intermittently elicit adrenal cortex responses but random samples may miss these. Regular sampling of blood, using cannulated animals gives more reliable information than infrequent measures of resting levels (Ladewig and von Borrel 1988). Tests of adrenal function are capable of revealing whether animals have frequently used adrenal cortex responses because frequent use results in greater synthetic enzyme activity. The major test used is to challenge with an injection of sufficient adrenocorticotrophic hormone (ACTH) to produce maximal glucocorticoid secretion. The magnitude of this glucocorticoid production response indicates the frequency or severity of adrenal cortex responses that housing conditions have produced.

In some circumstances it appears that animals do show a greater response to ACTH after experiencing difficult conditions over a long period. For example, sows which have often been in fights but have lost have a larger cortisol response to ACTH challenge than sows which have avoided conflicts or have won most of their contests (Mendl *et al.* 1992). Confined calves (Friend *et al.* 1985) and pigs at high stocking density (Meunier-Salaun *et al.* 1987) have also been reported to show a high response to

ACTH challenge. Other difficult conditions, however, do not elicit repeated adrenal cortex activity and do not result in elevated cortisol production following ACTH challenge (Ladewig and Smidt 1989). If the conditions are prolonged and very severe in their effects, adrenal function may be impaired and a reduced response to ACTH challenge may result. Hence whilst an increased cortisol response to ACTH challenge indicates poor welfare, the lack of such a response does not necessarily indicate that the conditions posed no problem for the animal.

2. The release of glucocorticoids from the adrenal glands exhibits both diurnal and ultradian variability, so that secretion occurs in a pulsatile or episodic fashion (Ladewig and Smidt 1989). When assessing the effects of housing conditions this necessitates a very intensive schedule of sampling in order that endogenous fluctuations in glucocorticoid levels do not obscure the effects of the experimental treatment (Ladewig 1987). Various studies have demonstrated that the frequency and amplitude of endogenous secretory episodes must be taken into account when measuring corticosteroid levels (Ladewig 1984). An additional factor that has to be considered is that the plasma concentration of corticosteroids is not only dependent upon the rate of hormone secretion, but also upon its rate of clearance from the blood.

3. The nature of the aversive stimulus may influence the animal's reaction to it (Mason and Mendl 1993). Increased glucocorticoid levels have been associated with states of fear and anxiety, while pain does not always affect plasma glucocorticoid concentration (Rushen 1986, Bateson 1991). Prolonged pain can result in a reduced corticosteroid concentration (Lay *et al.* 1992).

Different species may show distinct responses to a similar stressor. For example, bulls have been reported to show a reduced corticosteroid response to ACTH challenge after 5 weeks of tethering (Ladewig and Smidt 1989), while male pigs show an increased response to ACTH following a similar period of tethering (von Borell and Ladewig 1989). Species differences in response to pain have been reviewed by Bateson (1991). Breed and individual differences also exist in the secretory activity of the adrenal cortex (von Borell and Ladewig 1989, Zhang *et al.* 1990, von Borell and Ladewig 1992).

A final but most important point concerning the use of measurements of adrenal cortex activity is that the sampling itself usually causes an adrenal cortex response. It is therefore essential, in all but ACTH challenge studies, that the blood or saliva sample be taken quickly enough to avoid spurious results caused by disturbance to the animal during sampling. The sampling disturbance effect will commence as soon as any approach to the animal is made in all but animals thoroughly habituated to human proximity. Saliva samples are easier to take and cause less disturbance to the animal in most circumstances.

Work on endogenous opioids and other neuropeptides may also be useful in relation to assessing pig welfare.

1.7.2 Catecholamines

Noradrenaline and adrenaline present more difficulties with respect to sampling than corticosteroids, as they are released within 1 or 2 seconds of the animal's perception of the stimulus. Their measurement has not so far been of use in the assessment of the effects of housing systems. However, measurement of enzymes which synthesise catecholamines may be useful.

1.7.3 Heart rate

As with glucocorticoids, heart rate is influenced by factors other than fear and anxiety. The level of heart rate reflects the animal's general metabolic demands, and is also influenced by circadian rhythms. In order to avoid conflicting and equivocal results it is important to distinguish between metabolic and emotional effects and to ensure that the measurement itself does not cause much disturbance to the animal (Broom and Johnson 1993). Heart rate changes provide useful information about the effects of short-term problems on animals, but the measure gives little information about the long term effects of housing on animals. It is necessary to complement measurements of heart rate with other indices such as those pertaining to behavioural activity. An additional point for consideration is the equipment used to sample heart rate. Telemetric systems are the most effective, but the equipment may impede the animal's movement and it is important that the measurement of behavioural indices should be carried out simultaneously with the recording of heart rate data.

1.8 Immune response

The plasma white blood cell count is responsive to stress-induced changes in corticosteroid levels, but it can also be influenced by a number of factors unrelated to stress. Other immunological indices are more reliable, such as the ratio of eosinophils to lymphocytes and the activity of certain populations of lymphocytes such as T helper cells and T suppressor cells. Some very accurate *in vitro* methods have been developed to assess the proliferation of T cell cultures when exposed to mitogens. A possible drawback with the use of such methods is that immune system reactivity may decline with age in certain species (Manser 1992). Notwithstanding this, levels of suppression of lymphocyte division have proved to be more sensitive indices of welfare than alternative measures, such as the total lymphocyte count, the proportion of different types of lymphocyte in the plasma and delayed hypersensitivity (Broom and Johnson 1993). Another immunological index that can be used is the activity of natural killer cells. It is necessary in such studies to distinguish changes in immune system function which are sensitive to acute events but have no serious consequences, from changes which indicate real problems for the animal.

1.9 Injury and disease

1.9.1 Injury

Injuries caused by other pigs, by humans or by contact with the immediate physical environment can be quantified in animal welfare studies. For example, de Koning (1983) described a method of quantifying lesions on sows. Most of the lesions in sows or boars are caused by fighting and are scratches or cuts on the skin. In sows and gilts the vulva is an occasional target. The degree of injury is usually scored according to the depth of the wound and by its length. Such scoring is also usually related to the delay before healing is complete and the extent to which the healed wound is still evident. The reason for singling out bites to the vulva as worthy of mention is that such injuries may result in profuse bleeding and may lead to some vulval distortion after healing.

Another kind of injury which is often quantified in pig welfare studies is tail injury caused by biting. Although the motivation of the pig which bites the tail is likely to be investigation, manipulation and perhaps feeding rather than aggression, the consequence for the bitten pig is serious. Bitten tails may attract further biting so that the injury is to the abdomen at the base of the tail after the tail itself has been bitten off. Infections may also result when the tail or adjacent areas are bitten.

1.9.2 Disease

Methods for assessing disease in pigs are of particular importance in welfare studies since all disease results in poorer welfare, some disease conditions being worse than others. The importance of the disease depends not only on the incidence or risk but also on the duration of the disease and on the intensity of pain and discomfort which a diseased animal experiences. (Willeberg 1991). When comparing systems and practices, the incidence of infectious disease is a relevant measure. The techniques for recognising signs of disease are legion and will not be described here. If systems did vary in this respect, infectious disease would be an important factor but in general they do not since it is human practices with regard to the likelihood of transmission between units which are the most important variables (see Chapter 4.7). However, diseases of young piglets can vary considerably with management methods.

Production related diseases are of great relevance in considering welfare in relation to housing conditions and management practices. Among the major diseases in this area are clinical conditions of the legs and feet which result in lameness, urinary tract infections, reproductive system disorders, mastitis and other conditions affecting lactation, cardiovascular disorders and certain joint problems. In each case, clinical analysis of severity is possible and a combined measure of frequency and severity can be used in the assessment of systems.

1.10 Growth, reproduction and life expectancy

If developing animals are not able to grow or if mature animals are unable to reproduce despite good opportunities to do so then their welfare is poor. Hence these measures can be used to identify particularly poor welfare. Welfare is also poor if a housing and management system results in a lower life expectancy, in the absence of human interference, than that which would normally be expected in such animals.

1.11 Conclusions

1. Pigs have needs which must be fulfilled in order to safeguard their welfare. Such needs include obtaining adequate nutrients, performing certain species-specific behaviours, taking sufficient exercise and adopting adequate movements and postures to avoid maldevelopment of muscles, bones and joints, avoiding injuries, disease and parasitism, and living in adequate social surroundings.

2. Recommendation: The person responsible for the pigs should ensure that their welfare, including their health, is safeguarded by the use of appropriate housing, feeding, care, vaccination, preventive medicine and veterinary advice and treatment. Pigs should be inspected daily by the caretaker for signs of poor welfare, such as bodily condition, movements and postures, condition of skin, eyes, ears, legs, feet, and tail. Other signs of ill health include listlessness, loss of appetite, laboured breathing, excessive salivation, vaginal discharge, frequent coughing, swollen joints, lameness and scouring. Attention should also be paid to the presence of external parasites, to the condition of faeces and to feed and water consumption.

3. The welfare of pigs is assessed by a combinations of a variety of methods, including behavioural measurements, such as preference tests, aversion tests, measures of motivation and abnormal behaviour, physiological measurements, health measurements and performance measurements.

4. Conclusions about welfare should always be based on all available evidence, properly weighted, and should not rely only on, for example, preference or other trials in experimental conditions, or epidemiological surveys. When recommendations about modified practices are produced, the relevance of experimental studies where effects of only one or a few factors have been varied, must be carefully considered. On practically operating farms, effects of such single variables may be exaggerated or compensated by other factors, and the stockman factor is central in the effective functioning of a particular system. It is therefore normally desirable that on-farm surveys are carried out before definite recommendations are issued.

CHAPTER 2 PIGS IN NATURAL AND SEMI-NATURAL CONDITIONS

2.1 Domestication and history

The domestic pig originates from the European Wild Boar, and was probably domesticated between 5000 and 10000 years ago (Clutton-Brock 1981). The wild boar is widely distributed throughout the Old World and occupies a variety of habitats and niches (Frädrich 1974). It is a quite variable species within the genus Sus, which contains five recognized species and several sub-species (Groves 1991). Domestic pigs have been introduced and feralized in large numbers in the New World, and they breed and spread in the wild to the extent that they are often considered to be pests (Dzieciolowski *et al*. 1992, Giles 1977, Graves 1984a, Hanson 1959b).

Studies of Wild boars, feral pigs and of domestic pigs kept in semi-natural enclosures are the main sources for understanding the natural behaviour of pigs. Although domestication and selection has altered basic aspects of the anatomy and physiology of the pigs, comparisons reveal that no major changes in basic behavioural systems have occurred during domestication; rather, behavioural differences between the different genetical lines of pigs appear to be of a quantitative nature (Frädrich 1974, Graves 1984a). In an attempt to understand the basic ”design” of pigs, and thereby to understand the welfare requirements of the species, we need to consider also the behaviour of the wild relatives. In this chapter, ”wild pigs” or ”wild boars” both refer to undomesticated individuals of the species *Sus scrofa*, whereas ”feral pigs” refer to domesticated pigs which since several generations live in the free without specific protection from man. ”Domestic pigs” refer to breeds of domesticated pigs with no history of feralization, even if some of the observations which will be discussed have been made on animals kept in semi-natural enclosures for research purposes.

It should always be remembered that modern breeds of pigs, kept under farming conditions, differ from their ancestors in many biological functions. However, it is also likely that many evolutionary adaptations of the wild boars still prevail in some form in domestic breeds. When comparative data, like those reviewed in this chapter, are properly analysed, they may provide some insights into possible needs of pigs and some basis against which to interpret welfare problems that are identified in other chapters of this report. In reading this chapter, it is essential to note in which of the above-mentioned breeds that any observation has been made. An observation in only wild boars can as most be suggestive, whereas observations from wild boars as well as feral pigs and domestic pigs under semi-natural conditions are more likely to reflect a fundamental evolutionary adaptation which may still be present in modern pigs. Although the modern domestic pig has retained many behavioural characteristics of wild boar, some of these have changed, for example the threshold for anti predator responses.

2.2 Social structure and social behaviour

Both Wild Boars and feral pigs are gregarious animals (Frädrich 1974, Graves 1984a). The basic social unit is the maternal group; herds appear to be formed by long-time associations between mothers and their female offspring (Mauget 1981), and the most common group sizes are two to six individuals (Graves 1984a). During a period around farrowing, and some weeks thereafter, mothers are mostly seen on their own with their litters, whereas males (both adults and subadults) are commonly solitary, although they also frequently form all-male groups, which appear to be less stable over time than the family groups (Graves 1984a). Since pigs are prey animals, group living is believed partly to be an anti-predator strategy, which is supported by the way in which vigilance behaviour is adjusted in the presence of conspecifics (Quenette and Gerard 1992).

The gregarious nature is obvious also in domesticated pigs. Within groups, they form stable, linear-approaching hierarchies, based on age and size (Beilharz 1967, Ewbank 1976, Meese 1973, Puppe and Tuchscherer 1994). Individual recognition is largely based on smell, whereas sight is relatively unimportant once the social order is established (Baldwin 1974, Ewbank 1974a, Ewbank 1974b, Meese 1975). Although pigs possess a repertoire of different vocalizations, only the function and/or signal content of a few of them are known (Kiley 1972a, Klingholz 1979b). This includes the warning call, sow lactation grunts which transfer information concerning the milk ejection during a suckling episode, "begging calls" of piglets and contact grunts (Algers 1984a, Jensen and Algers 1982, Kiley 1972b, Klingholz 1979a, Weary and Fraser 1995).

2.3 Home range

Wild boars and feral pigs are not territitorial, i e they do not defend a specific area against conspecifics, but they live in restricted areas, so called home ranges, and a specific individual or group shows a high degree of site fidelity (Graves 1984a). Sizes of home ranges appear to vary widely; different studies report sizes between less than 100 ha and more than 2500 ha (Barrett 1978, Kurz 1972, Mauget 1980). Males are reported to have larger home ranges than females, but the size of the home range appears most strongly determined by food availability (Graves 1984a). There are no data on home ranges of domestic pigs, although pigs in semi-natural enclosures tend to use the available space extensibly (Wood-Gush *et al*. 1990).

2.4 Activity pattern, thermoregulation

In wild pigs, the daily activity pattern is highly variable and depends to a large degree on hunting pressure, where heavily hunted populations tend to be more nocturnal in their activity rhytms (Graves 1984a). Weather also determines the rhythm, so that the animals tend to be passive during periods of strong heat (Hanson 1959a).

In a study of domestic pigs in a semi-natural enclosure in Sweden, activity was found to be concentrated to some hours in the morning and the late afternoon - early evening, with resting periods in the middle of the day and during nights (Wood-Gush *et al*. 1990). In this study, pigs would move between selected foraging areas during their activity periods and rest on one out of a few resting sites used day after day. More or less permanent resting sites are also known from feral pigs and wild boars, and these sites are frequently formed into resting nests, by means of the pigs bedding with grass, twigs and other bedding material (Graves 1984a). Similar bedding behaviour has been described for pigs in enclosures (Stolba 1984b). Since pigs - wild and domestic alike - have very limited sweating and panting abilities, they rely on wallowing for cooling in hot weather (Baldwin and Ingram 1967).

2.5 Foraging and nutrition

All pigs are omnivorous animals and readily adapt their diets within wide limits to the prevailing conditions. In wild boar and in feral pigs, the basis of the diet is usually plants and plant based food items (grass, roots, fruit, berries, seeds, etc), but animals may constitute a substantial part of the diet (Hanson 1959a). Remains of both invertebrates such as earth worms and small vertebrates such as frogs and rodents have been found in stomach contents of feral pigs (Hanson 1959a).

Even when fed full rations of commercial feed, domestic pigs have been noted to spend 6-8 hours searching for food in a semi-natural enclosure (Wood-Gush *et al*. 1990). Much food searching is performed by rooting, but grazing and browsing are also prominent foraging behaviours (Wood-Gush *et al*. 1990). Unpublished detailed studies of the post-feeding behaviour of free-ranging domestic sows has shown that the pigs often spend one to two hours performing elaborate sequences of foraging behaviour. The exact type of foraging behaviour varies with the season, and may be grazing or browsing when vegetation is abundant, otherwise it is mostly rooting (Jensen, unpublished observations).

The adaptiveness in foraging behaviour is illustrated by the observation that feral pigs may adopt the habit of attacking, killing and eating new-born lambs (Giles 1977).

2.6 Exploration

In an omnivorous species such as the pig, some exploration is expected to be closely linked to foraging behaviour. Exploration develops early under natural conditions and constitutes a substantial part of the time budget of free-ranging domestic pigs (Petersen 1994). Pigs may be motivated to explore even if there are no obvious novel stimuli which may elicit the behaviour (Woodgush and Vestergaard 1993).

2.7 Sexual behaviour

Wild boars and feral pigs have pronounced seasonal reproductive periods, in most studies one or two major mating periods have been reported (Dzieciolowski *et al*. 1992, Mauget 1981), whereas domestic pigs breed more or less the year around.

At the time of breeding in wild and feral pigs, males join the maternal groups and court the sows in heat (Mauget 1981). Females are in heat for about 72 hours and during that time they actively search boars and maintain close proximity (Signoret *et al*. 1975). Boar sexual behaviour involves sniffing, urine sampling, massaging and pressing with the snout against the body of the sow, emission of specific courting vocalizations, and emission of foam from the mouth and urine containing pheromones; these stimuli act in a summatory fashion to enhance the receptive behaviour and subsequent fertility of the sow, effects which have been demonstrated in domestic pigs (Hemsworth 1978, Melrose 1971, Soede 1993). There are no fundamental differences between domestic pigs and wild boar in these respects.

2.8 Choice of farrowing sites

After a pregnancy lasting on average about 115 days both in wild and feral pigs, the sows show a remarkable change in behaviour in the period preceeding parturition. In wild boars and feral pigs, some studies indicate that behavioural change may begin already several weeks before parturition, manifested as a higher tendency to stay alone outside the normal home range for long periods of the day (Graves 1984b, Martys 1982). In domestic pigs in seminatural enclosures, sows leave the herd about 24-48 hours before farrowing and wander long distances outside the normal home range, apparently in search of a suitable nest site (Jensen 1987, Jensen 1988b).

The farrowing sites finally chosen have been studied in some detail for domestic sows in semi-natural enclosures, and they usually show some specific features: they are situated well outside the normal home ranges, they are protected horizontally towards at least one side by slopes or large stones, and they are protected vertically by branches (Jensen 1989).

2.9 Nest building

When the farrowing site has been chosen the sow commences nest building, which is a typical behaviour of wild and feral sows as well as of domestic pigs. The onset of nest building preceedes farrowing by about 16-20 hours, and this appears the same both in wild boar and in domestic pigs (Gundlach 1968, Jensen 1989, Jensen *et al*. 1993).

Both in wild pigs and in domestic pigs in natural surroundings, nest building consists of an initial phase of rooting and pawing, followed by fetching, carrying and arranging grass or other soft material (Gundlach 1968, Jensen *et al*. 1993). Experimental studies of domestic pigs have demonstrated, that even though the behavioural sequence is sensitive to environmental cues, the behaviour is essentially triggered by hormonal changes and is performed largely intact also in complete absence of relevant stimuli (Jensen 1993, Lawrence *et al*. 1994). The nest is mostly finished 2-4 hours before parturition and from that point the sow usually remains lying in the nest, a pattern seen in wild and domestic pigs alike (Gundlach 1968, Jensen *et al*. 1993).

2.10 Birth and neonatal behaviour

During birth the sows of wild, feral and domestic pigs lie still most of the time and unlike most other female mammals do not lick the young or aid them in tearing the umbilical chord or in getting free from fetal membranes (Gundlach 1968, Jensen 1985, Martys 1982). However, under free-range conditions, domestic sows sometimes get up and sniffs the young several times during the parturition, which usually lasts for about 4-6 hours (Jensen 1985).

In domestic pigs, the new-born young usually manage to find the teats within less than 30 min post partum and during a period of several hours they sample different teats and ingest colostrum (Fraser *et al*. 1995). Piglets failing to ingest colostrum within the first about 20 hours post partum will almost inevitably die (English 1975, Fraser *et al*. 1995).

In domestic pigs, within about 16 hours, the typical cyclical pattern of nursing, with nursing intervals of 40-60 min, have developed and the piglets will follow this rhythm of nursing and resting (Castren *et al*. 1993, Fraser *et al*. 1995).

2.11 Maternal behaviour

Under free-range conditions domestic sows remain in the nest and its close surroundings with the piglets for a period of about 10 days (Gundlach 1968, Jensen *et al*. 1991, Stangel and Jensen 1991). During this period, a teat order is formed and the unused teats dry up, which has also been reported for wild boars (Gundlach 1968, Jensen *et al*. 1991, Stangel and Jensen 1991). The sudden abandoning of the nest marks a change in the strategy of the piglets from mainly acting as "hiders" to acting as "followers" (Jensen and Redbo 1987).

Suckling in domestic pigs is usually performed with the sow lying down, particularly in the early lactation, and is characterised by a series of distinctive phases, including pre-massage (about 40-60 s), milk ejection (about 20 s) and final massage (30 s - 10 min) (Fraser 1980). During the suckling, the sow grunts rhythmically with an increasing grunt rate, reaching a peak about 20 s before milk ejection (Fraser 1980).

2.12 Weaning

In some sense, aspects of weaning start already during the first week of life in free ranging domestic pigs (Jensen *et al*. 1991), but is not finished until the pigs are on average 13-17 weeks, a weaning age that is similar to wild boars (Gundlach 1968, Jensen 1995, Newberry 1985). Weaning in free-range domestic pigs is characterised by a gradual decrease of suckling frequency, increased proportion of piglet-initiated and sow-terminated sucklings, increased pre-massage time and shortened post-massage time and an increased frequency of sucklings performed with the sow standing; this has been interpreted as the sow inferring an increased cost of maintaining lactation on the piglets (Jensen and Recén 1989, Jensen and Stangel 1992).

2.13 Social integration/mixing

Under free-range conditions, domestic pigs enter the herd when they are about 10-14 days old, after the farrowing nest has been abandoned, and prior to that point they have usually not met any pigs apart from their mothers and litter-mates (Jensen and Redbo 1987). The weeks thereafter are associated with a high social activity, but little overt fighting, and the social activity stabilizes at about 8 weeks post partum by which time the pigs may be regarded as being integrated in the group (Petersen *et al*. 1989). However, even if the integration process is completed, social bonds between litter mates continue to be stronger than other bonds in the group (Newberry 1988).

Under free-range conditions, some piglets develop the tendency to suckle from mothers other than their own (Jensen and Stangel 1992). Whereas some piglets suckle opportunistically on several mothers, others get completely adopted and integrated into another litter (Goetz and Troxler 1993). This is sometimes considered as a problem when lactating sows are kept with their piglets in groups, since it may cause negative effects on the piglets exposed to the cross-suckling piglets (Goetz and Troxler 1995). The gradual integration process is in sharp contrast to the intense fighting usually going on in practice when pigs are mixed (Fraser and Rushen 1987).

2.14 Sexual maturity

Domestic pigs reach sexual maturity earlier than wild boars, at 7-9 months compared to 18-24 months (Mauget 1981, Prunier 1984). The age at puberty is influenced by genetic, social and environmental factors and is lower when animals are in a group, are in contact with boars and are not spatially restricted (Brooks 1970, Ford 1978, Kirkwood 1979, Kirkwood 1981, Prunier 1984).

2.15 Summary and Conclusions

5. When kept under free-range conditions, pigs live in small social groups, show a variable diurnal rhythm and have strongly developed exploratory behaviour. At birth, sows farrow in social isolation and construct a nest prior to parturition. Weaning is gradual, is completed only after about 13-17 weeks, and piglets are gradually integrated into the herd with little obvious aggression. It should be borne in mind that selection has modified many aspects of pig biology.

CHAPTER 3 PRODUCTION SYSTEMS - OVERVIEW

This chapter aims to briefly review the nature of commercial pig production and the types of housing system within use.

3.1. Types of pig production enterprise

Pig production enterprises may specialise in piglet production (often referred to as ‘sow herds’ or ‘breeding herds’), in the production of slaughter pigs from purchased piglets (often referred to as ‘fattening herds’, ‘finishing herds’ or ‘feeding herds’), or may carry out both of these functions within the same unit (‘farrow to finish herds’). A more recent development is the ‘sow pool’ unit, which produces pregnant sows, sends them to satellite farms just before farrowing and takes the same sows back from these farms at weaning to be rebred and spend pregnancy in the sow pool unit. Breeding herds typically sell their piglets as ‘weaners’ at 20-30 kg liveweight (9-12 weeks of age), although some herds will sell the piglets immediately at weaning or as older ‘store’ pigs. Slaughter pigs are generally sold at 90-110 kg liveweight, although the most typical weight varies in different countries. In some countries there is still a market for lighter ‘pork’ pigs slaughtered at about 60 kg.

Some production herds breed their own replacement breeding stock, but it is more common to purchase these animals from specialist breeders. Gilts (young females) and boars are typically purchased at 5-6 months of age, although sometimes they are purchased at 3 months and reared within the herd. Of the herds specialising in the production of breeding stock, ‘nucleus’ herds are at the top of the breeding pyramid and practise very intense genetic selection. They produce the grandparent stock for commercial sow production, and supply breeding boars for commercial use. ‘Multiplication’ herds (or ‘multipliers’) use sows and boars from the nucleus herds to produce commercial breeding gilts for sale to production farms.

Large units typically operate on a continuous flow basis, with farrowings, weanings and services taking place each week. However, a common alternative which is increasing in popularity because of potential advantages in operating with larger batches of animals is the three-week system (Le Denmat *et al.* 1984). In this system, the herd is divided into 7 batches of sows, with batches farrowing at three week intervals. This allows weekly specialisation of tasks such as farrowing, weaning and service or artificial insemination, so that greater focus can be put on each operation. The larger group size facilitates ‘all-in all-out’ operation of rooms, with thorough cleaning and disinfection between batches, so that pigs of different ages are not present within the same room and risk of cross-infection is reduced. Only the pregnancy accommodation contains pigs from different batches at the same time. A further extension of this approach is the Isowean or multi-site production system. In this system, the sows, weaned piglets and finishing pigs are housed on separate sites to prevent disease transmission between pigs of different ages (see section 5.4).

3.2 Choice of housing systems

Pig production enterprises may keep their pigs outdoors, or in indoor housing systems which vary from being relatively extensive to very intensive in nature.

3.2.1 Outdoor systems

Systems in which breeding sows live in free-range, outdoor conditions have been traditionally used in many countries (Thornton, 1988). Originally these were developed as low input, low output systems either as part of an integrated arable rotation or utilising less productive areas of land. In recent years they have again increased in popularity in some European countries as a result of their low capital cost and flexibility and of the increasing consumer demand for meat coming from production systems which they perceive to provide high welfare for the animals. They can only operate successfully in areas which have an appropriate soil type and climate, which limits their applicability within the EU. At present, they account for 20-25% of breeding sows in the UK, about 10% in France and <1% in other countries (Edwards, 1995; see also Appendix 6.4).

Some national herd recording schemes indicate that modern outdoor systems achieve the same average production level (pigs weaned per sow per year) as indoor herds (MLC, 1995), but more comparisons (Easicare, 1995; Dagorn *et al.* 1995) indicate poorer average performance by 1-2 pigs weaned per sow per year. The breeding animals live in groups in fenced paddocks, with communal shelter provided for dry sows and boars, and individual huts for farrowing and lactating sows. The communal huts are most typically half-round, corrugated-iron arcs, but more recently larger tents constructed of big straw bales and polypropylene roofing have gained popularity. Farrowing huts are smaller corrugated-iron or wooden arcs, which are sometimes insulated. Many different designs exist, which may sometimes incorporate floors or anti-crush bars. Young piglets are usually kept inside the hut by a threshold or fender, whilst sows can come and go freely.

On most outdoor units, the piglets are removed at weaning to indoor housing. However, the use of outdoor weaner housing is increasing. Systems in which the piglets run freely around a field are not common, with most enterprises favouring an insulated kennel with outdoor run bounded by hurdles. Similar systems exist for finishing pigs, but are not commonly used because of the difficulty of management and maintenance of hygiene. Tent systems in enclosed paddocks for growing/finishing pigs are also used, but again are not common.

3.2.2 Indoor Systems

Indoor systems can be divided into 3 categories based on the manure handling system adopted. The proportion of farms using housing with straw bedding varies widely between different countries in the EU (see Appendix 6.4), but unbedded housing greatly predominates overall.

a) Deep litter systems

In these systems, the total area occupied by the animals is maintained in a clean, dry state by regular provision and removal of absorbent bedding material. In such systems the animals will often subdivide the pen area into separate lying and excretory areas, choosing to lie in the most thermally comfortable and undisturbed areas and excreting in areas of the pen which are cold, wet or draughty. Advances in farm mechanisation, especially the use of large straw bales, have made it possible to automate the bedding and cleaning processes in systems with large, covered yards. However these are only applicable in areas where straw, or some similar material, is cheap and plentiful.

Whilst straw is the most commonly used material in such systems, there has recently been development of deep litter systems using sawdust beds, in some cases with anaerobic digestion of waste being promoted by regular application of an enzyme/microbe mixture (Kay and Smith, 1992).

b) Scraped systems

In these systems the lying and excretory areas are made structurally distinct and the manure is removed at frequent intervals from the excretory area, often daily. This manure removal is accomplished by use of a tractor-mounted or automatic scraper system. Such systems have the advantage of requiring little or no bedding and operating successfully at lower space allowances for the animal.

A recent development is the 'Straw-Flow' system, which offers new scope for designing bedded systems with a low requirement for material and labour (Bruce, 1990). With this system, the animals live in a pen with a sloping floor and straw is provided from a freely accessible dispenser at the top of the slope. The fresh straw gradually moves down the slope as a result of gravity and the activity of the pigs to a dunging passage at the bottom, from which it can be removed by an automated scraper system.

c) Slatted systems

Slatted housing systems are most widely used throughout the EU. In these systems hygiene is maintained, usually in the absence of any bedding, by installation of slatted floors through which the excreta can fall and be stored in a physically separate place from that occupied by the animals. Removal of the need for bedding makes such systems applicable for use in non-arable locations and minimises overall farm labour requirements. Systems may be fully slatted over the entire pen area, or have a solid floored lying area combined with a slatted dunging area. More recently, slatted systems designed especially to reduce ammonia emissions have been developed (den Hartog *et al.* 1996).

3.2.3 Environmental control

Pigs require a certain air temperature to achieve thermal comfort and good performance (see Section 4.3). This can be achieved in a number of ways. The most appropriate method in any given circumstances will depend on the climate of the region and availability of bedding material.

a) Natural ventilation

If natural ventilation is adopted, there is less possibility to regulate air temperature inside the building. Such a system will therefore only work well where the climate is very warm, or where deep bedding can be provided to allow the pigs to form a micro-climate. In cooler climates, it can be advantageous to provide localised kennelling of the lying area, by placing a roof (with or without a front barrier) over part of the pen. This restricts air movement and heat loss from the immediate vicinity of the animals so that their body heat can give rise to a significantly warmer microclimate. However the provision of kennelling makes management more difficult since such tasks as provision of bedding, cleaning of pens and inspection of animals are hindered by more restricted space and poorer visibility.

b) Controlled ventilation

Greater control of the thermal environment can be achieved by use of thermostatically controlled ventilation systems. These use changes in ventilation rate, combined where appropriate with additional sources of heating, to maintain a set temperature despite ambient fluctuation. This necessitates higher capital and running costs for the building. Insulation of the building structure helps to maintain such environmental control.

Fan-controlled ventilation can operate on positive or negative pressure within the room (Baxter, 1984). Pressurised systems with air outlets below the slatted floor help maintain better air quality for the pigs by preventing the updraft of noxious gases from slurry. Different air flow trajectories are possible, for example high speed jet ventilation systems are designed to maintain correct temperature and airspeed differential between lying and dunging areas, assisting maintenance of pen cleanliness in part-slatted systems.

3.3 Boars and service

Service may be carried out either by natural mating with a boar or by artificial insemination (AI). In some countries natural mating in most common, whereas in other countries AI predominates. Most farms, even those using only AI, will keep at least one boar to assist with oestrus stimulation and detection. Replacement breeding boars are typically purchased at 5-6 months of age from specialised breeders. They begin their working life at about 6-7 months of age and, on most farms, are sold after 2-3 years when they have become too large and are superceded by the next generation of genetically more improved animals.

Mature boars are normally housed individually to facilitate staff safety and service management. Group housing is more normal in outdoor systems, where traditionally service is carried out by a team of boars living with a group of sows. Boars maintained at AI studs are typically housed in individual pens. The keeping of boars in individual stalls where they cannot turn round was common in the past but is now prohibited under the terms of Directive 91/630. Stud boars are trained to mount a dummy sow for semen collection which typically occurs once or twice weekly.

Gilts and sows awaiting service are most often housed singly or in small groups to facilitate oestrus detection and handling. The housing system adopted may be any of those described in the subsequent dry sow section, although large groupings are uncommon.

Gilts are normally served for the first time at their second or third oestrus after puberty, at 6-8 months of age. Sows are typically served at their first post-weaning oestrus, which usually occurs 4-7 days after weaning. Service typically takes place in the boars pen, or in a specially designed mating area. Sometimes, however, the boar is allowed to remain with a group of sows and serve them as they come on heat. Sows which do not conceive will return to oestrus approximately 21 days later. Animals which do not return to oestrus can be checked for pregnancy by ultrasonic methods from 28 days after service.

3.4 Dry sows and replacement gilts

Replacement gilts are typically reared in groups, in the same way as slaughter pigs, until transfer to the breeding herd. It is most common for these gilts to be housed separately from older sows until completion of their first lactation.

Breeding sows may be housed individually, in stable groups (formed at weaning or service and remaining unchanged until farrowing) or in large dynamic groups (where existing sows are removed to farrow and replaced by newly served sows on a regular basis). Individual housing may be in fully enclosed stalls or in partial stalls where the sow is tethered by a collar or girth belt (tethering will banned in the EU after 2005). Sow stalls are the most widely used housing system within the EU because they allow individual rationing, prevent aggression, are easy to manage and occupy little space. However, in some member states, the use of individual stalls for pregnant sows has been made illegal or is currently being phased out. Whilst the use of group housing varies widely between different countries (see Appendix 6.4), it is still the minority system throughout the EU as a whole.

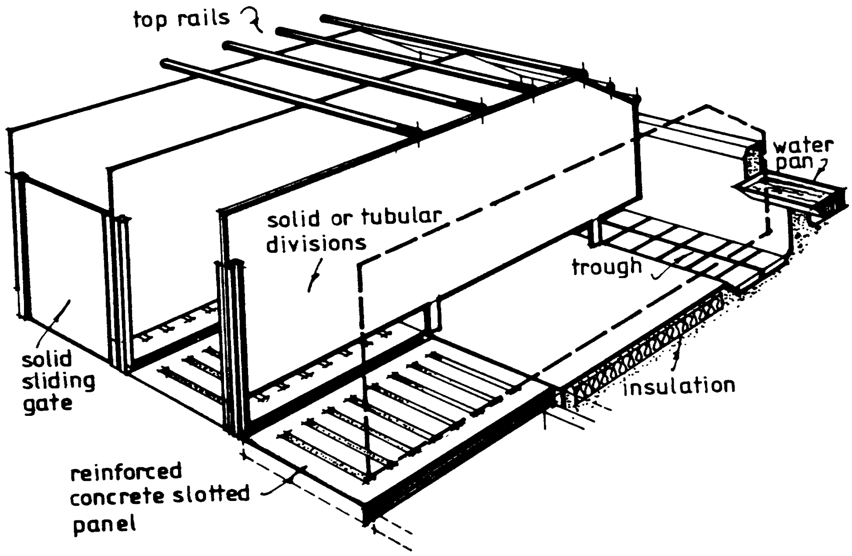

Fig 3.1. Stall housing for pregnant sows

a) Individual housing in stalls

Individual stalls typically allow the sow an area of 0.6-0.7 x 2.0-2.1 m, such that she cannot turn around and excreta are deposited at a fixed location (Fig 3.1). There are many different stall designs: with good designs the stall width is adapted to the body size of the sow, the partitions are barred or meshed to allow visual contact but prevent aggression and the height and fixing position of the bottom rail are appropriate to avoid injury. Flooring is most commonly partially slatted, although both fully slatted and bedded systems do occur. Sows commonly have a trough which is either individual or communal (4-6 sows) to allow the possibility of keeping sows of the same body size or condition in adjacent stalls. Feeding may be manual or automatic (1-3 times per day) and feed may be given dry or wet. Wet feeding systems can vary from the simple dropping of individual dry ration into water to complex pipeline distribution systems from a central, computer-controlled mixing facility.

The design of group housing systems is highly influenced by the constraints imposed by current sow feeding practice. Dry sows are typically fed a relatively small amount of a concentrate diet in one or two daily meals, and a number of different options are available for feed delivery to group housed animals:

b) Group housing with floor feeding systems

The traditional way of feeding group housed sows, and the way still used in almost all outdoor units, is to distribute the total allowance of feed for the group on the ground and leave each individual to eat as much as it can until all feed has disappeared. In indoor housing, systems of this nature have been automated using equipment developed for growing pigs in which feed delivered by auger is measured into a dispensing canister and subsequently dropped onto the floor once or twice daily (dump feed systems) or thrown out over a wider area (spin feed systems).

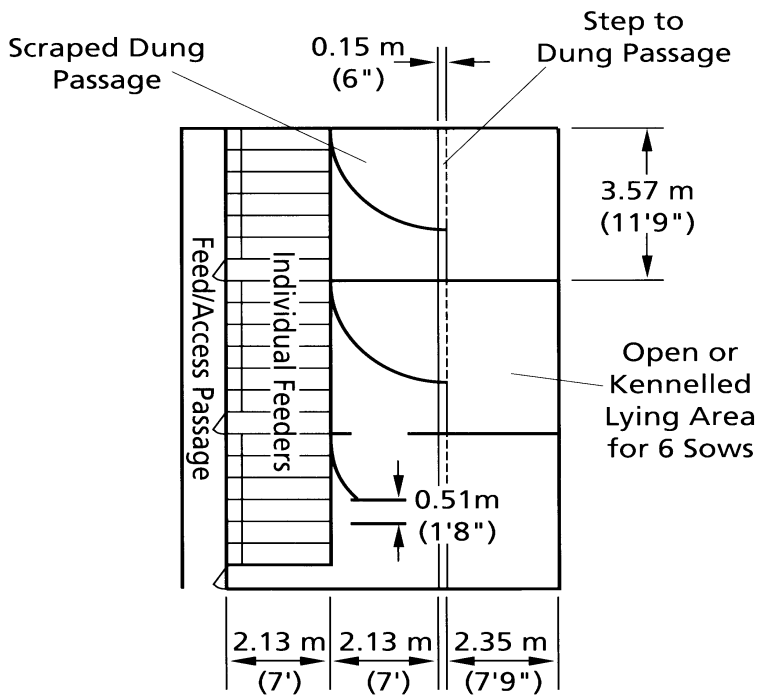

Fig 3.2. Group housing for pregnant sows with individual feeding stalls

c) Group housing with individual feeding stalls

Precise rationing of each individual animal without aggression can only be guaranteed by individually confining the animals at the time of feeding. This is achieved by the temporary use of individual feeding stalls in conjunction with group housing systems (Edwards, 1985). These stalls each accommodate one animal who can then be fed as an individual during a short period once or twice daily, and share a communal area for the rest of the time (Fig 3.2). Individual feeding stalls are expensive in terms of cost and occupation of building space if they are used for only a short period each day, and can increase capital cost by 74% in comparison with a floor feeding system (Edwards and Robertson, 1988). This cost can be reduced by time sharing of the feeding stalls between several different groups, but the associated increase in labour requirement means this option is not popular.

Capital cost can be greatly reduced by combining the feeding stall and lying area, as is done in systems with cubicles or free access stalls (Edwards, 1985; Hoofs, 1990) (Fig 3.3). This can reduce space allowance and capital cost by 23-26% (Edwards and Robinson, 1988). Whilst it is desirable to have a manual or sow operated back gate on each stall to prevent fast eating animals from displacing other sows, this is often deemed unnecessary in practice with carefully matched sows in small groups on similar feed levels.

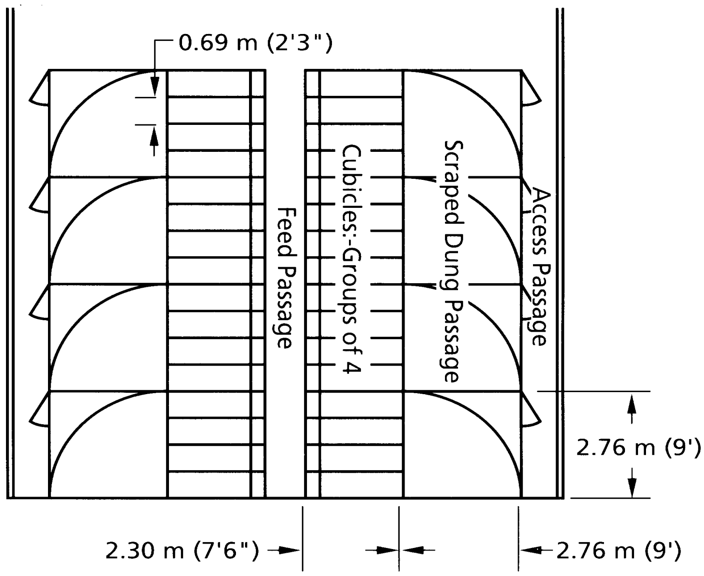

Fig 3.3. Cubicles housing for pregnant sows

d) Group housing with automated flat rate individual feeding

Further cost savings can be made by reducing the length of feeding stalls, such that only partial barriers are used (Petherick *et al.* 1987). This leaves more free space in the pen for other activities. Without an enclosed stall, it is not possible to avoid problems of feed poaching by fast eating sows. One way in which these have been minimised is to use a 'biological fixation' (Biofix or ‘trickle feed’) system, in which feed is delivered by auger at the same controlled rate to each individual place. Since the sows cannot then eat at a differential speed, movement between feeding places gives no benefit and only partial barriers are necessary (Bengtsson *et al.* 1983; Hoofs, 1990).

An alternative method for automated flat-rate individual feeding which overcomes the space constraints of a simultaneous feeding system is the 'two yard' system (Hunter, 1988). In this system each group of sows occupies two adjacent pens, with an automatic feeding station between them. All sows are initially placed in one pen with access to the station. They enter the station sequentially, and each sow mechanically triggers a sequence of events comprising closing of the rear gate and feed dispensing. After feeding, the sow exits via a side gate into the other pen, which contains only animals which have passed through the feeder. Sows which have not fed by the end of the day remain in the first yard to await attention.

e) Group housing with automated individual identification and rationing

Refinement of the two yard system can allow some degree of individual feeding, since it is now possible to operate up to four different feeding levels at the same station by tagging specific categories of sows. This is not individual recognition, but simply a signal for a different feed level for any animal carrying the triggering tag.

Greater refinement is now possible with the development of automated individual rationing systems based on the out-of-parlour feeding system developed for dairy cattle (Lambert *et al.* 1983; Edwards and Riley, 1986). In this system animals must feed sequentially at one or more feeding stations controlled by a central computer. Each individual is identified on entry to the station by an electronic transponder carried on a collar or ear tag, or as an implant. A precisely measured individual ration of food is then dispensed to that animal and she is protected while eating by a specialised feeding stall with gates operated by the sow herself or by the computer. A single feeding station can be shared by as many as 40-60 sows, and very large groups of animals can consequently be kept in low cost, unspecialised housing (Brade *et al.* 1986; Hunter, 1990) (Fig 3.4).

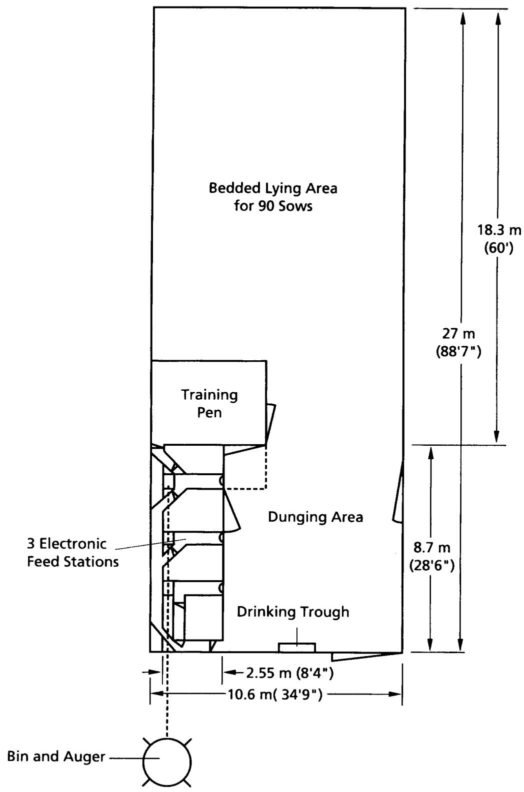

Fig 3.4. Group housing for pregnant sows with Electronic Sow Feeder (ESF)

To overcome the problems associated with sequential feeding, new systems are being investigated in which groups of sows feed concurrently in stalls, but where differential rations can still be fed to electronically identified individuals (Morris and Hurnik, 1990; Hoofs, 1990). These are not yet common in commercial practice.

f) *Ad libitum* feeding systems

These are not in common use because, when fed *ad libitum* on conventional concentrate diets, dry sows will eat to excess and become obese. This problem can be overcome by the use of specially formulated bulky diets of low nutrient density (Brouns *et al.* 1990) and simple hopper feeding systems adopted. Systems in which roughages such as silage are fed *ad libitum* in conjunction with supplementary concentrate are also practised (Livingstone and Fowler, 1983). Another way in which the advantages of *ad libitum* feeding have been utilised without giving rise to obesity is by means of interval feeding systems (Mahan and Murray, 1977). Such systems have been developed in North America but not widely adopted in Europe. In these systems the animals are given *ad libitum* access to feed for a limited time period only, for example an 8 hour period every second day or a 24 hour period twice weekly.

3.5 Farrowing and lactation

Sows are typically moved from dry sow to farrowing accommodation 3-7 days before the expected farrowing date (115 days after service).

In outdoor systems, farrowing and lactating sows are housed in either individual or group paddocks, with access to individual farrowing huts. In indoor systems, the use of farrowing crates for this period predominates. These crates, typically 2.0-2.4 x 0.6m in size, are designed to restrict the movement of the sow and placed centrally or offset in a pen which has specialised provision for the young piglets (Fig 3.5).

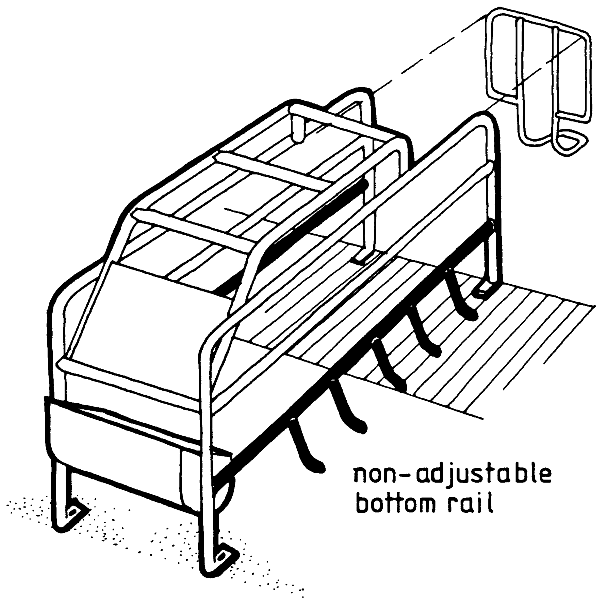

Fig 3.5. Design of a typical farrowing crate

This 'creep' area may be a simple heat source (hanging lamp or heat pad) or may be an enclosed area to maintain higher temperature (Fig 3.6). The tethering of the sow in partial crates is an alternative option, but will be precluded under the terms of Directive 91/630. In some member states, the use of farrowing crates is already restricted to a limited period around the time of farrowing. However, in the EU as a whole, the use of farrowing crates throughout lactation is the predominant system (see Appendix 6.4).

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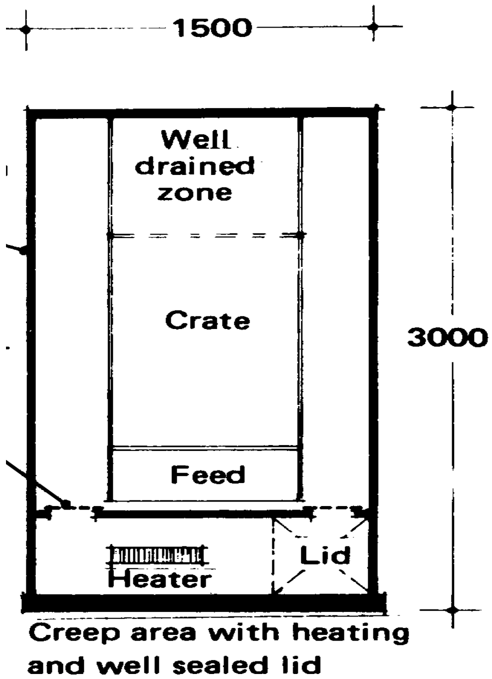


Fig 3.6. Farrowing pen plan showing farrowing crate and piglet creep box.

The use of individual pens for the farrowing/lactating sow and litter is common only in countries where farrowing crates are no longer allowed. These may be simple pens of approximately 2.8 x 2.2 m with anti-crushing rails around the walls (Fig 3.7) or pens with separate lying and dunging areas (Fig 3.8**)**. These pens sometimes contain a temporary crate structure which can be made by moving a partition into place at the time of farrowing.

Alternative designs of intensive farrowing pen, which still have slatted flooring but allow the sow to turn around, have been developed but are not yet widely used in practice. These include the Ottawa crate (Fraser *et al.* 1988), which uses inward-sloping bars to limit the area where the sow can lie and to control the lying movements of the sow, whilst still allowing her space to turn around, and the ellipsoid crate (Lou and Hurnik, 1994), which has bowed out sides to give space for turning. Another alternative, which eliminates the crate entirely, is the sloped floor or "hillside" pen (Collins *et al.* 1987). These pens are comparable in size to a crated pen (1.8 x 1.8 or 2.3m) with a slope of 10-17% on a fully slatted floor and a heated creep area at the base of the slope. Another alternative farrowing pen design which does use bedding is the "Schmid box" (Schmid, 1991). In this pen (2.5 x 3m) a bedded nest area is separated from an activity area (with feeding and drinking facilities) by a division which contains a heated creep box.

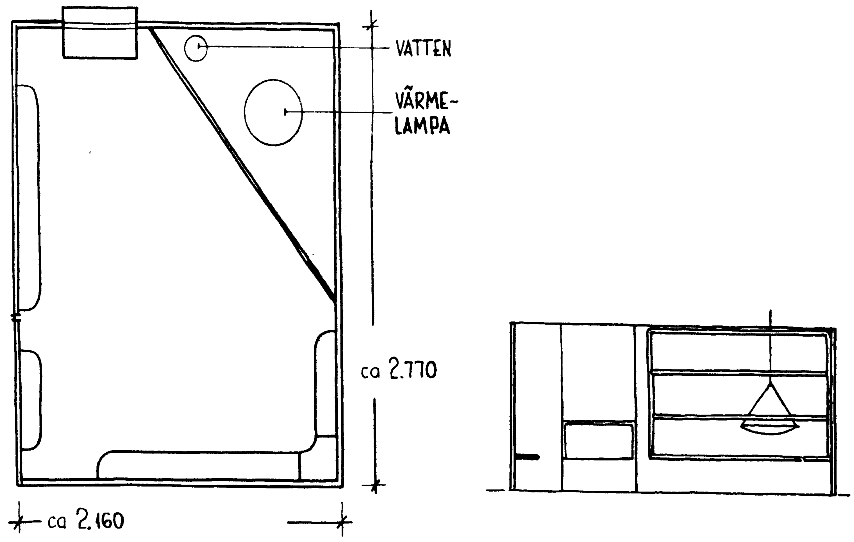


Fig 3.7. Farrowing pen accomodation for sows maintained loose during farrowing.

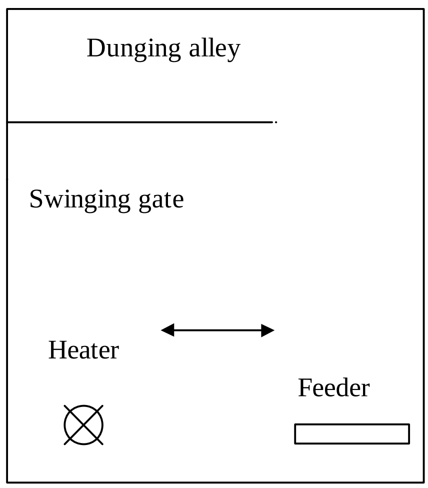


Figure 3.8. Loose farrowing pen with temporary crate

Recently, some indoor group-farrowing systems have also been developed, where sows have individual farrowing nests and access to a communal area. These include systems with simple nest boxes (Fisher, 1990; Algers, 1991; Kavanagh, 1995), small square nest pens with heated creeps (van Putten and van de Burgwal, 1990; Houwers *et al.* 1992; Boe, 1993; Goetz and Troxler, 1993; Rudd *et al.* 1993), or specially designed, highly sophisticated nests such as the Freedom Farrowing system (Baxter, 1991). At the present time, none of these are used to any significant extent in commercial practice.

Sows are fed once or twice daily, or may be given *ad libitum* access to food. Piglets are typically offered supplementary food starting at 1-2 weeks of age, although some enterprises operating early weaning (at 3 weeks) may not offer 'creep' feed.

Most sows remain in the farrowing crate or individual pen throughout lactation. However, in some cases sows and litters may be grouped in a 'multisuckling' system once the piglets are established (Wattanakul *et al.* 1997). The age at which this occurs can vary from 2-3 days to 2 weeks.

3.6 Weaning and weaners

Weaning typically takes place abruptly at between 3 and 5 weeks of age, although some farms still wean as late as 8 weeks (see chapter 5.4). At this time, the sow is returned to service accommodation, and the piglets either left in the farrowing pen for a period or moved immediately to the weaner accommodation.

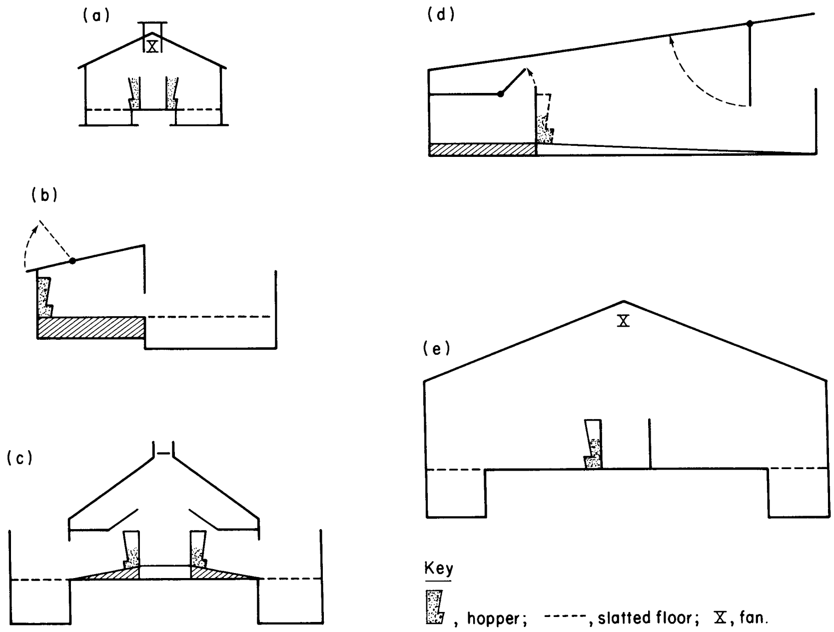


Fig 3.9. Housing for weaned and growing pigs. (a) Flat deck pens, (b) Weaner kennel, (c) Kennel pens with verandah, (d) Weaner kennel in monopitch, (e) Part slatted finisher accommodation, (UFAW, 1988)

A variety of housing systems for weaned piglets exist (Lean, 1988). Tiered cages house small groups of pigs on fully-slatted floors, typically in highly controlled environments with supplementary heating. Flat decks are again fully-slatted but open-topped for easier access, and in single or double tiers (Fig 3.9a). Kennelled systems include 'bungalows', with enclosed lying areas and outdoor, slatted dunging areas (Fig 3.9b and c). Similar enclosed lying areas with outdoor scraped passageways can also be found. Kennels can also be used in deep litter systems, typically in monopitch buildings (Fig 3.9d) or large straw courts.

Weaned pigs are typically fed *ad libitum* on high quality diets, although some enterprises restrict feed intake in the immediate post weaning period to prevent digestive disturbance. Wet feeding systems which provide food ‘little and often’ or *ad libitum* are also being used to an increasing extent.

If intensive housing is used, pigs will be moved from the first stage weaner accommodation to larger, second stage accommodation after 2-4 weeks. If more extensive housing is used, weaners may remain in the same pen until 30-40 kg or, in a few instances, until slaughter.

3.7 Fattening pigs

Accommodation for fattening pigs may again be fully slatted, partly slatted (Fig 3.9e; Fig 3.10), minimally bedded with scraped dunging area or deep bedded with straw or sawdust. Although there are national differences, housing with fully or partly slatted flooring predominates within the EU (see Appendix 6.4). Feed may be provided either wet or dry. Dry feed is often given *ad libitum* from one or more hoppers, although feed may be restricted in the later stages to prevent excessive fatness in pigs of unimproved genotypes or very heavy slaughter weights. Restricted feed is provided either wet or dry in long troughs, 2-3 times daily, or by widespread distribution of dry feed onto the floor in the lying area.

In controlled environment housing, it is normal to use 2 or three housing stages, each with larger pens, in the growing/finishing period to make most efficient use of space. In more extensive housing, for example large straw-bedded courts, the same pen may be used throughout.

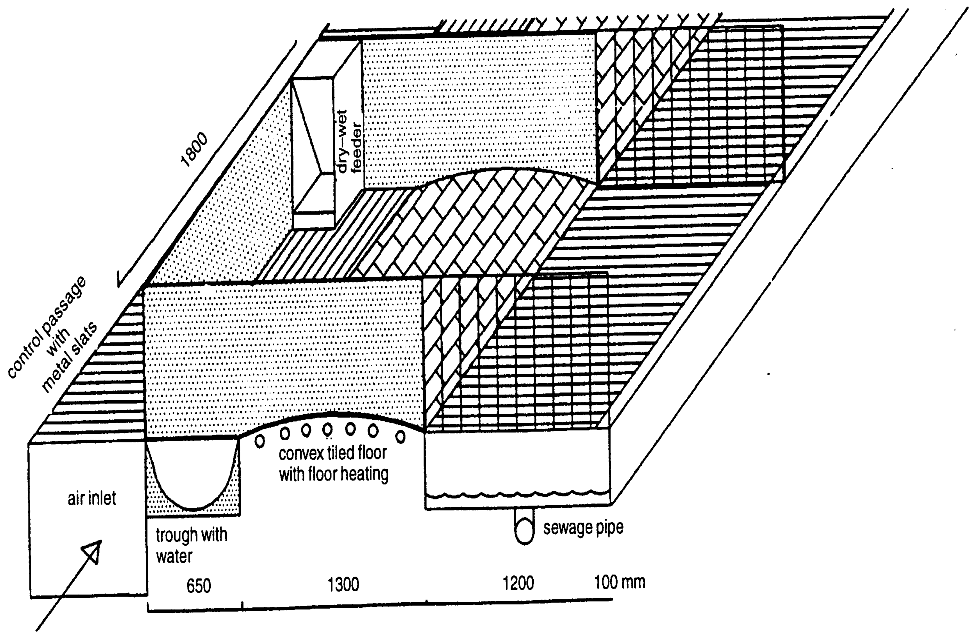


Fig 3.10. Pen for growing/finishing pigs designed to minimise environmental pollution (den Hartog *et al.* 1996)

3.8 Conclusion

6. A variety of different husbandry systems are in commercial use. Pig herds may specialise in piglet production ("sow herds" or "breeding herds"), in production of slaughter pigs from purchased piglets ("fattening/finishing/feeding herds") or may have both functions in the same unit ("farrow to finish herds"). Within each type of enterprise, there are several different possibilities for housing systems, depending on national legislation, regional conditions and economic circumstances.

CHAPTER 4 SPECIFIC HUSBANDRY FACTORS AND PIG WELFARE

4.1 Flooring, Bedding, and Substrates Providing Enrichment

4.1.1 General needs for flooring and bedding

Chapter 4.1 is concerned with physical characteristics of flooring and bedding materials, health and hygienic aspects of these materials for pig husbandry and deals with the general behavioural needs of pigs including the role of substrates in providing enrichment. Other aspects like space, nutritional value of bedding material and environmental aspects are mainly discussed in other sections. However, bedding material such as straw has several different aspects which are attractive for the pig (i.e. odour, rooting and chewing material, nutritive value, insulation, nest building material) that cannot be discussed independently of each other.

There is a general agreement in the literature that floors must not be slippery, so as to prevent injury, and the lying area has to be clean, well drained and comfortable to prevent any adverse effect on the pig. Where provided, bedding material should be dry, clean and not harmful to the pig when chewed or eaten.

4.1.2 Technical aspects of flooring (insulation, conductivity, surface material)

Pigs are either kept on slatted or partially-slatted floors of different materials, or on solid surfaces with bedding. From a technical point of view, flooring materials in unbedded systems should have sufficient perforation or slot width to keep the pens clean from faeces. On the other hand, pigs have a need for a high proportion of solid area for their comfort, with small slot width to prevent injuries. With increasing weight of pigs, the roughness of the flooring surface becomes critical, in that heavier animals slip on smooth materials like expanded metal or plastic slats. Piglets in farrowing crates are often kept on plastic slats or plastic coated wire, whereas most flatdecks are equipped with various types of metal flooring (e.g. cast iron), with a trend towards plastic-coated expanded metal or plastic slats. Uninsulated expanded metal or bare wire flooring are characterized by a high conductivity, causing physical and thermal discomfort, mainly in very young (suckling-) piglets that have a need for a solid and warm insulated lying/creep area. Wire metal flooring has been banned in some countries because of its risk of causing injuries. Woven wire with a diameter of at least 5 mm does not seem to cause leg problems in piglets (Smith and Mitchell, 1977). Fattening pigs and sows during gestation are typically kept on concrete slats. Lactating sows in crates have different thermal requirements to those of their offspring and therefore are often kept on metal flooring, to prevent thermal heat stress in a room that has to be kept relatively warm for the piglets. Fattening pigs, as well as sows, spent most of their lifetime on concrete floors.

Pigs prefer to separate their dunging/activity area from their lying area. Partially-slatted pens with a solid area (bedded or not) allow for this behaviour, although solid areas may become dirty if the pen is inadequately designed (i.e. open side panels between solid areas of neighbouring pens) or other factors like social stress/crowding and climatic factors lead to this problem. Arched solid-tiled areas in the middle of a pen which has metal/concrete slats in the rear and front are usually kept clean by pigs, and allow for a functional separation between the dunging and lying area. Den Hartog *et al*. (1996) described a pen design for growing-finishing pigs that consists of a slatted area for feed and water consumption, a heated solid area for resting and a slatted tri-bar area for defaecation. Pigs tend to use the solid part of the pen as a dunging area at the end of the finishing period, when pen size (i.e. 0.56 m^2/pig) becomes critical (Pedersen and Jfrgensen, 1991).

4.1.3 Health and hygienic aspects of flooring and bedding

Newborn piglets often develop abrasion injuries on their front legs from contact with the floor during suckling activity (Furniss *et al*. 1986). Phillips *et al*. (1995) provided a small area of cushion flooring for piglets that reduced the incidence and size of skin injuries on the forelegs. Rearing of pigs aged 3-8 weeks on perforated flooring was found to result in a higher frequency of traumatic injuries to extremities than rearing in pens with a concrete floor (Algers, 1984).

For hygienic reasons, faeces and urine have to be separated from the pigs' lying area by means of slotted flooring or litter that has to be regularly renewed and kept dry. Pigs that are exposed to noxious gases deriving from deep manure pits under the animals living space, wet bedding material or badly ventilated buildings can develop respiratory diseases, as well as behavioural alterations causing tail biting and cannibalism (Boon and Wray, 1989, Fraser, 1975, van Putten, 1980). Usage of tri-bar slats, manure flushing systems, air inlet conditioning and compost bedding can reduce ammonia emission substantially (Van den Weghe, 1996). Irritation of ocular, nasal and respiratory tract membranes is observed after brief exposure to the highest ammonia concentrations in piggeries. Passive avoidance operant conditioning revealed that pigs avoid acute exposures to peak (100 ppm) ammonia concentrations while ammonia concentrations of 40 ppm did not influence the proportion of the food consumed. A concentration of 40 ppm ammonia only becomes aversive after prolonged exposure (Jones *et al*. 1996). The pigs' respiratory system can also be negatively affected by dust, deriving from bedding material or dusty feedstuffs. Many of the organisms that cause respiratory infections are attached to dust particles which are inhaled by the animals, and a reduction in dust levels makes a major contribution to a reduction in the overall challenge to the animals (Boon and Wray, 1989).

Factors that need to be taken into account in the design of slats are the size of the slots, the surface roughness and the edge design (Boon and Wray, 1989). Smooth surfaces and deep litter systems may cause excessive hoof growth, leading to standing/walking abnormalities and lameness (Geyer, 1979; van der Wal *et al*. 1984). Lameness is considered to be a major cause for the culling of adult pigs (Barnett *et al*. 1984). Some abrasion is a necessary prerequisite for foot health, and underworn hooves can be just as big a problem as overworn ones (Webb and Nilsson, 1983). Bar width and slotted space between bars of perforated floors need to be adjusted to the pigs' size as indicated in Table 4.1.1, which summarizes recommendations from 15 sources for piglets, growing/finishing pigs and sows (Mulitze, 1989).

Table 4.1.1 Recommended bar and slot width for concrete flooring in pigs representing a range from 15 sources (modified after Mulitze, 1989)

	Piglets	**Growing**	**Finishing/Sows**
Slat width (mm)	50 - 120	75 - 150	80 - 200
Slot width (mm)	9.5 - 22	12.5 - 25	17 - 30

4.1.4 Stimulatory aspects of bedding and substrates providing enrichment

Pigs that are provided with bedding (mainly straw) are reported to be more active and exhibit increased rooting and exploratory behaviour when compared to pigs housed on bare flooring without any bedding (Arey and Franklin, 1995; Beattie *et al*. 1995). The effects of straw on the well-being of pigs can be divided into at least three categories (Fraser, 1985): (1) floor-comfort effects due to the straw's texture, thermal insulation and drainage properties; (2) recreational effects, as straw provides an outlet for chewing, rooting and other behaviour; (3) dietary effects, as the consumption of straw can compensate for lack of bulk in the diet. Oral behaviours of pigs in barren environments often become re-directed towards pen fittings and other pigs (McKinnon *et al*. 1989). Therefore, a major function of straw is to provide a stimulus and outlet for rooting and chewing, resulting in a reduction of such activities directed at pen-mates (Fraser *et al*. 1991). Destructive behaviours like tail biting or oral stereotypic activities (i.e. bar biting) are reported to be reduced by straw (Fraser, 1975, 1985, Fraser *et al*. 1991; Spoolder *et al*. 1995). Dailey (1995) suggested that stereotypic behaviour shown by sows is more substrate than environment dependent. Provision of straw does not reduce fighting between newly-mixed growing pigs (Arey and Franklin, 1995).

Wood-Gush and Vestergaard (1991) stressed the importance of exploratory behaviour for the welfare of pigs. Their study with pigs kept in spacious pens with straw indicated that novelty was still rewarding for them. It was concluded that novel items should be provided. Heizmann *et al*. (1988) studied the behaviour of fattening pigs in a straw-bedded pen that were offered one of the following play objects: chain, dehydrated tendon, tyre and a bone (humerus from cattle). Although pigs made use of all four objects, the frequency of exploratory and play behaviours was greatest with the bone. However, interest in all objects decreased as a function of decreasing novelty. Provision of toys such as rubber hoses to chew on, and contact with people inside the pens, reduced excitability in pigs (Grandin, 1989). Apple and Craig (1992) investigated the influence of pen size on toy preference of growing pigs. It was concluded that pigs receiving a small pen space allowance spend more time playing with toys than pigs with a large pen space allowance. Amongst the different toys offered (a knotted nylon rope, a rubber hose, a brass-plated chain and an hourglass-shaped dog toy), a soft, pliable rubber dog toy was suggested for enrichment of confined pigs. In general, destructible materials elicit more attention from young pigs. Grandin and Curtis (1984) found that young pigs preferred to chew cloth strips rather than harder materials, Feddes and Fraser (1993) showed that cord with a frayed end attracted much chewing behaviour and Geskell and Broom (in prep) have shown that destructible wood with bark on it elicits more chewing and is habituated to more slowly than a block of wood with no bark. The role of straw as a substrate to manipulate after restricted feeding in pig housing of low complexity was discussed by von Borell and Hurnik (1991).

4.1.5 Early experience and animal preference testing

In a series of experiments, Schouten (1986) investigated the effects of early experience on later behaviour in pigs. It was found that vital behaviours like feeding, drinking and suckling were not strongly influenced by rearing conditions. Great differences between rearing conditions were described for exploratory and redirected exploratory behaviour (massaging or nibbling at littermates or sow). Enrichment of the environment (i.e. provision of bedding) increased exploration only temporarily. Impoverishing the environment decreased the exploratory behaviour, but to a lesser extent. De Jonge *et al*. (1996) demonstrated that the amount of stereotyped activity displayed in tethered sows depends on their rearing condition. Pigs that were reared under impoverished conditions exhibited increased stereotyped activity compared to animals reared under enriched conditions, independent of the feeding level.

During the last decade, new methods have been developed to assess motivational aspects of pigs for certain features in their housing environment. Numerous choice experiments by Marx and Schuster (1986) revealed a relative preference of piglets for insulated flooring material compared to bare expanded metal or wire flooring. Also, flooring types with a high proportion of solid area relative to the slotted part are preferred. Hoof health, when assessed on flooring that had been chosen by piglets, was not necessarily positively correlated with the preferred type of flooring. Piglets might prefer concrete flooring, causing leg and claw problems in the long run, in comparison with plastic slats with a relative high proportion of perforation between slats or coated wires, where claw health problems are less prevalent. Although motivation analyses provide good data about animal preferences and their strength, they must be interpreted with some care because animals may choose things which are bad for them (Broom, 1996).

Experiments that examined the combined preference for space and flooring type revealed a relatively higher preference for flooring features than for space allowance *per se*, indicating the importance of physical and thermal comfort of flooring material (Marx and Schuster, 1986). The choice for certain flooring features or bedding materials depends on the thermal conditions in the pigs' housing environment. Pigs might prefer to lie on wet and cool surfaces during hot summer days. Deep litter systems (including compost bedding) might create problems during summer when pigs do not have access to areas or features allowing the animals to cool down. Therefore, under warm conditions, straw is likely to benefit pigs because of its recreational value but not as a means of improving comfort in the resting area (Fraser, 1985).

New alternative housing systems (usually in open or uninsulated buildings) tend to allow the animal to choose between different thermal and functional environments. These systems are usually run with larger group sizes compared to conventional systems (Nürtinger System; Straw-Flow^R (Arey and Bruce, 1993); open-front system; outdoor housing with huts etc.). The stimulatory importance of certain bedding materials has been studied recently by operant conditioning procedures (Matthews and Ladewig, 1994; Hutson, 1992). This method allows measurement of the relative strength of motivation for certain factors, in that the animal has to "work" for getting access to stimuli (like straw) by pushing a button or nose plate. In the context of nest building behaviour of sows, the intensity of performance of rooting and pawing behaviour prior to farrowing appeared to be independent of external nest-building stimuli (Hutson, 1992). Jensen (1993) studied the role of external stimulation triggering and controlling nest-building. Their findings support the conclusion that gathering and arranging nest material largely depends on external stimuli, whereas the preparation of the nest site (initial phase of nosing, rooting and scratching) is triggered by internal factors. The provision of straw from racks to group housed gilts with an ESF (Electronic Sow Feeding System) had no effect in reducing the amount of injuries on their hindquarters (Krause *et al*. 1997, in press).

4.1.6 Conclusions

7. The needs of pigs which are affected especially by artificial flooring are: to have comfort when lying and avoidance of injury, to minimise the risk of disease, to thermoregulate adequately in any high or low temperatures which might be encountered. Where floors are perforated or slatted, rather than solid, hygiene may be improved by reducing the contact between the pig and the faeces/urine. The risk for claw injuries is less on solid flooring than on perforated flooring. Some perforations or slats in floors may trap claws and the solid section between perforations or slats may be too narrow to support the foot evenly.

8. Recommendation: The size, construction and maintenance of slats, slots and perforations should be suitable for the size of the claws of the pigs kept on that floor, in such a way that the likelihood of trapping, discomfort whilst standing or walking and injury is minimised.

9. Pigs have a preference for insulated or bedded flooring providing physical and thermal comfort. In hot conditions, possibilities for being cooled by the floor may be more important to the pigs than physical comfort or insulation provided by a bedded area. Hence deep litter or compost systems may create thermoregulatory problems in pigs kept under high ambient temperatures.

10. Bedded flooring not only influences comfort, it also provides for investigatory and manipulatory activities and, in the case of straw, may provide dietary fibre and allow pigs to express feeding behaviour. Only straw of good hygienic quality should be used.

11. Earth floors suitable for rooting and objects or materials for manipulation and exploration provide environmental enrichment in barren housing. Deformable materials, such as wood with bark on it or thick rope, is especially attractive to pigs. When artificial objects are provided, however, the interest in manipulating these objects decreases as a function of decreased novelty.

12. Recommendation: Pigs should be able to choose appropriate functional conditions. Except in buildings where the temperature is adequately controlled, pigs should also be able to choose appropriate thermal conditions.

13. Recommendation: All pigs should be provided with a lying surface which is physically and thermally comfortable and which does not result in injuries. Materials for investigation and manipulation, which may be bedding material or earth floors suitable for rooting but need not be, should be provided whenever possible for pigs.

4.2 Social structure and mixing

As the domestic pig originates from the wild boar it has generally maintained, among other characteristics, the same social structure. As shown earlier in this report the social group reflects the maternal group, being formed by one sow and her litter and, eventually, by the sow and her female young (Frädrich 1974). This organisation remains almost stable until the next oestrous of the sow, when the boar joins the group. Thus, the mean group size is of 2 to 6 sows (Graves 1984). The domestic pig is then equipped to display the necessary behaviour useful to develop a social hierarchy, but is obviously structured for a relatively small group size and is likely having difficulty to maintain a stable social hierarchy when compelled to be housed in large groups or at high density. An exception is around weaning age, when litters under free-ranging condition join together and the group of piglets form even large groups (Jensen and Redbo 1987, Petersen *et al*. 1989).

4.2.1 Social dominance

In swine a particular form of social dominance hierarchy develops very early, well before full independence of piglets. In fact, a more or less stable "teat order" (called also "nursing order") rises on the day after birth among littermates. Although McBride (1963) stated that it has no relationship with the dominance hierarchy displayed by adults, it is likely that the energetic costs of establishing the social rank of group members are greater than necessary to maintain it. It is then reasonable to hypothesise that the nursing order of piglets represents the basis for the dominance hierarchy of adults, although it is not the same phenomenon (Scheel *et al*. 1977). As the piglets are born, they position themselves on specific teats which they will continue to use in a more or less exclusive way until they are weaned. Once a teat is "occupied" the piglet usually defends it against littermates, leading to establishment of the teat order. It is formed within 48 hours after farrowing and remains stable during lactation (Ewbank 1976). A negative correlation between the piglets' birth weight, birth order and location of the preferred teat has been repeatedly ascertained (e.g. Fraser 1975, Hartsock and Graves 1976) leading the early born and heavier piglets to suckle at the anterior teats, which generate produce more milk, leaving the posterior ones to the last born, weaker piglets. However, it is uncertain whether the anterior teats give more milk because of inherent capacity to do so or because of better stimulation by the more vigorous piglets (Fraser 1973). The teat order seems to represent the starting point for the maintenance of a segregation of littermates based on their weight and strength. Fraser and Morley Jones (1975) recorded that the difference of birth weight persisted 3 weeks later.

When unacquainted weaned pigs are mixed for the first time they engage in ritualised fighting for more than 24 hours to develop a dominance hierarchy. Heetkamp and co-workers (1995) calculated that fighting causes an increase of energy needs of 1.3%, which accounts for the small effect of fighting in young pigs. After mixing, at about 8 weeks of age, there is an increase of heat production of 57%, caused by increased activity in connection with the development of the social hierarchy. Nevertheless, that increase has no long-term effects. Agonistic behaviour is very similar to that observed in wild boars (Schnebel and Griswold 1983, Barrette 1986) and consists mainly of head knocks, butts, body side pressing and even bites. The biting is rarely severe, although the skin is easily lacerated (Fraser 1974, Jensen 1980, Rushen and Pajor 1987). This occurs in pre-weaning piglets as well. However, age does not represent an indicator of probability of fighting paired encounters but is correlated with the amount and duration of fighting (Jensen 1994). The hierarchy is usually fairly stable in its organisation within a few days (van Putten and van de Burgwal 1970) and rather linear (Ewbank 1976, McCort and Graves 1982, Brouns and Edwards 1994), although it is possible to record frequent changes of rank, particularly among the middle ranks. This fact accounts for the maintenance of a continuous, although minimal, level of aggression among groups even long after grouping (Csermely and Wood-Gush 1986). Very large groups of pigs seem to be able to form some sort of social organisation and the upper limit for the number of pigs in a particular group is unknown.

However, Ewbank (1976) reported that farmers prefer not to form groups of more than 25 pigs because larger groups have continuous, although low, level of aggression. In contrast, groups of less than 25 animals readily sort themselves out and the aggressive outcomes are only occasional. Although the number of 25 pigs cannot be considered a rigid threshold, it seems in accord with considerations from the natural condition of the social group of pigs which evolved to live in relatively small groups and maybe have not developed the ability to discriminate and remember all the individuals and their social rank in a large group.

The hierarchy is established among competitive dominance social encounters which usually have short duration (a few seconds) but can sometimes continue intermittently for several minutes. However, Jensen (1982) and Jensen and Wood-Gush (1984) ascertained that grouped-housed sows, as well as free-ranging ones, likely regulate themselves developing also an avoidance social order that acts together with the dominance order. Behaviours involving physical contact between animals do contribute the most to the formation of the social hierarchy, as shown by their continuous decrease in frequency over time (McGlone 1986, Blackshaw *et al*. 1987, Csermely and Wood-Gush 1990b). Social rank of grouped sows has been found to affect feeding behaviour. In fact, when pigs are not fed *ad libitum,* food presentation can result in competition for gaining the resource with consequent disadvantage for the low-ranking sows. In such a context, Csermely and Wood-Gush (1986) recorded many more agonistic interactions when sows were competing for food than when food was absent, and the behaviour patterns displayed by sows during interactions varied in the presence or absence of food in the pen. The highest incidence of competition for food was noted within 30 minutes after food delivery, showing a decline later in connection with disappearance of feed from the pen. In this period, high-ranking sows remained at the centre of the mash pile formed on the ground defending the food against other sows (Csermely and Wood-Gush 1990a). While the total time spent feeding was similar in dominant and subordinate sows, the former interrupted feeding more often whereas subordinate sows stopped feeding for longer periods, due to the attacks by high-ranking sows. Moreover, Brouns and Edwards (1994) could record less weight gain among low-ranking sows housed in floor-fed pens but not in *ad libitum* pens. High-ranking outdoor sows reach higher liveweight and have longer duration of feeding episodes. However, the wider space allowed in that context determines low levels of aggression during feeding and the low-ranking sows are not disadvantaged as in the indoor housing (Martin and Edwards 1994). A restriction in feeding space increased competition for food in free-ranging sows leading to exclusion of subordinate sows from feeding (Signoret *et al*. 1995). As a consequence, subordinate sows spent less time feeding and then their fatness was clearly worse than that of dominants. Differences in feeding have been noted even with a computer-controlled feeder (Hunter *et al*. 1988, Tanida *et al*. 1993). In fact, the order of access to the feeder reflected the social hierarchy in the group and dominant sows were able to exclude subordinate sows from the feeder by repeated non-feeding visits, limiting the available time low-ranking sows had for feeding. However, Nielsen and co-workers (1995), who observed the amount of competition among 34 kg pigs penned in groups of 5, 10, 15 or 20 with available space of 1.06 m2/pig and one single-space computerised feeder, noted that group size had no effect on the mean number of attempts to displace penmates from the feeder. Social rank acquired during pregnancy by group-housed sows leads to differentiate maternal behaviour as well (Csermely and Nicosia 1991). The sows who were dominant during pregnancy were more active than subordinates in the 24 hours preceding farrowing but not after parturition, whereas subordinates displayed more frequently stereotyped and/or redirected behaviour patterns and were much more restless from the early days after farrowing. In addition, they interrupted nursing more frequently in the early days of lactation.

4.2.2 Agonistic behaviour at mixing

Starting from weaning pigs are often repeatedly mixed with unfamiliar individuals. Pigs have usually been put together on the basis of weight similarities, and obviously of the age, but regardless of their original litter. Soon after mixing they start to engage in fighting to establish their relative social rank and form the social hierarchy. The habit of mixing pigs is a consequence of the need to reduce adverse effects of fighting on daily food intake, although Sherritt and co-workers (1974) noted that mixed pigs tend to grow less than unmixed pigs. On the other hand, grouping weaned piglets of heterogeneous weight resulted in lower daily gain in the first 5 days after weaning than in groups of piglets uniform for weight (Francis *et al*. 1996). In contrast, uniform weight groups scored a higher incidence of wounding, even when providing structures which allowed low-ranking piglets to hide themselves behind them. However, as social hierarchy is perturbed not only by mixing unfamiliar pigs but even by the change of quarters, and this results in a certain amount of time spent in consuming energy for fighting and not in visiting the trough, the performance is negatively affected (Dantzer 1970, Petherick and Blackshaw 1987). It is then useful to limit changes of location and group disruption as much as it is possible. Ekkel and co-workers (1995, 1996) developed a Specific-Stress-Free housing system in which stress is prevented or minimised by raising pigs from birth to slaughter in the same pen and in possibly optimum conditions. They found that keeping litters intact improves health, welfare and production of growing pigs.

The amount of agonistic behaviour at mixing of finishing pigs is influenced by crowding and space availability, which will be discussed later in this report, and by the type of feeding pigs receive. Pigs fed *ad libitum* scored less agonistic behaviour than pigs which fasted for 24 hours before mixing (Kelley *et al*. 1980), whereas straw bedding in the pen had a significant effect on the reduction of aggression among fasted pigs but not in *ad libitum* fed ones (Arey and Franklin 1995). It has been pointed out that the individual pig has some peculiar characteristics of aggressiveness which seem to be pre-determined not only by the physical characteristics of the environment where the pigs are placed but also by some sort of personality of each pig (Mount and Seabrook 1993, Giersing and Studnitz 1996). Experience of isolation previously to grouping has very limited effects in comparison to group rearing (Moore *et al*. 1993).

Finally, it must be pointed out that chemical signals (pheromones) from pigs can modulate the aggressive output of penmates. Olfaction is the most important sensory system involved in agonistic interactions, although it is not the only one used. In fact, although temporary blinding lowered the amount of aggression displayed by unfamiliar pigs, anosmia induced by the olfactory bulb ablation had a much greater effect (Ewbank *et al*. 1974, Meese and Baldwin 1975). Two androgens, responsible for a meat taint, have been isolated from boars. One is found in the fat (5a-androst-16-en-3-one [androstenone]) and the other in the saliva (3ß-hydroxy-5-androst-16-ene) but both are not produced in castrated males at all (Patterson 1968 a,b, McGlone *et al*. 1986). Other pheromones modulating aggression were found in the urine and blood plasma (McGlone *et al*. 1987). In fact, 3 ml of those fluids applied with a brush on prepuberal castrated male and female pigs' ears, forehead, chin, chest and anal region caused a reduction of attacks if the donor was an aggressive pig but not if it was a handled castrated pig. In contrast, urine from fighting and non fighting intact males had similar effects on aggressive behaviour of test-pigs.

4.2.3 Reduction of aggression

Taking into account the adverse effects of aggression several attempts have been made to reduce fighting when pigs are grouped. As aggressive behaviours are still found among lactating piglets when they establish their teat order, Fraser (1975) observed that facial wounding was confined to litters with unclipped teeth. Removal of canine and lateral incisors reduced wounds to a large extent although this did not induce any significant change in the frequency of fighting nor in the growth rate between litters with or without clipped teeth. Weaning is another context where a great amount of fighting is developed. the provision of straw bedding or of barriers to hide behind were not useful to reduce either the frequency or the intensity of fighting in newly weaned piglets (Waran and Broom 1993, Olesen *et al*. 1995). In contrast, enrichment of the environment seems to be a major factor to inhibit fighting. Weaned pigs offered tyre and chain devices within the pen displayed a reduction in frequency of aggressive episodes (Schaefer *et al*. 1990, Simonsen 1990, Petersen 1995). This confirms previous observations (Arnone and Dantzer 1980) that a certain amount of aggression in grouped pigs originates from low environmental stimulation. Many farmers state that the method of mixing pigs either at feeding time, in pens with straw bedding or with low light if not in darkness was useful to reduce aggression and waste of energy. However, agonistic interactions seem to be almost inevitable even in adult pigs. In fact, they have been found in individually stalled sows as well (Dolf 1986) and the provision of straw bedding in pens of group housed growing pigs had very limited effect, although it was useful to reduce the incidence of other behaviour patterns, such as rooting and chewing on penmates (Fraser *et al*. 1991). Conversely, food and time of day have been found to affect the amount of fighting when adult pigs are grouped (Barnett *et al*. 1994, 1996). Low light intensity, in contrast, has no effect in reducing either the frequency of fighting, wound scores nor general activity of mixed pigs (Christison 1996). Allocating pigs in pens with food offered at the time of grouping in the morning or in the afternoon, or present *ad libitum* or at ration and grouping pigs soon after sunset or during daylight, Barnett and co-workers (1994, 1996) found that providing food *ad libitum*, but not rationed food, greatly reduced the amount of agonistic interactions among the group as well as the method of grouping after sunset. This may have been caused by pigs that maintained the habit to "settle" for the night after sunset.

In order to reduce the amount of aggression at mixing the use of tranquillizing drugs has been widely advocated for many years (Dantzer 1974) and has been of general use in pig husbandry. The substances most used are Amperozide and Azaperone, which result in very similar effects (Gonyou *et al*. 1988). They effectively reduce aggression among grouped pigs but their effect is limited over time and they cannot avoid a rise of the frequency of agonistic interactions to develop the social hierarchy at the end of the drug effect (Pascoe 1986, Csermely and Wood-Gush 1990b, Tan and Shackleton 1990). After that time limit the behaviour of treated pigs is then not different from that of non-treated grouped pigs. Amperozide was slightly more effective in reducing aggression and wounding among 30 kg pigs at mixing than azaperone but had the same temporary effects (Gonyou *et al* 1988, Pluske and Williams 1996). Blackshaw (1981) noted similar effects even on pigs mixed at weaning and also did not find any effect of the drug on the growth rate.

4.2.4 Physiological consequences

There are obvious connections between aggressive behaviour and the physiological condition of the individual pig. For instance, it has been known for long time that prolonged exposure of an animal to a non-escapable stressor, such as those frequently encountered in restraint or grouped pigs during agonistic interactions, may increase the amount of the corticosteroids and the adrenocorticotrophic hormone (ACTH) and/or interfere with the rhythm of their release (Arnone and Dantzer 1980, Barnett *et al*. 1985, 1987, Ladewig 1987). In contrast, Pedersen and co-workers (1993) did not find any correlation between the amount of aggressive attacks received by individual sows grouped after weaning and the concentration of either cortisol, oestradiol-17ß or prolactin. Mendl and co-workers (1992) instead investigated the relationship between the amount of aggressiveness and the involvement in agonistic interactions of pregnant primiparous sows and the concentration level of salivary cortisol. Sows defined as of "High Success", i.e. with high aggression score and high involvement in social interactions, scored higher levels of cortisol and produced higher litter weight of live piglets than sows of "Low Success". The differences in hormonal output caused by aggressive behaviour displayed or received by pigs has to be considered also in order to evaluate the quality of the meat. In fact, the analysis of carcasses of boars and castrates that fought or not during transportation and lairage revealed that the carcasses with greater damages scored higher concentrations of cortisol, glucose and lactate in blood collected at slaughter than those with limited or no damage (Wariss and Brown 1985). In addition, the analysis of meat revealed that the pHµ in the m.adductor and m.semimembranosus was higher in carcasses with the greatest wounds caused by aggression.

4.2.5 Conclusions

14. Apart from adult boars and sows around parturition, pigs are social animals.

15. Recommendation: Pigs should not be housed in social isolation, except for mature boars and sows at farrowing. [see also recommendation no. 64]

16. The welfare consequences of keeping pigs in large groups (more than about 15-20 pigs for growing finishing pigs and sows) are not well understood. Adequate individual inspection is important for welfare and is more difficult with large groups.

17. Recommendation: When pigs are kept in large groups, sufficient measures must be taken to allow individual inspection of the animals.

18. In general, the mixing of pigs results in poor welfare. The younger the pigs, the less severe are the effects on welfare of mixing pigs.

19. When mixing pigs, the welfare is better if the pigs are uniform in weight. Even if the immediate post-mixing aggression levels may be higher in uniform groups, size uniformity minimises the undesirable consequences for welfare of competition, especially that for food. When pigs are mixed, their welfare is better when they have adequate opportunities to withdraw and hide from other pigs.

20. Recommendation: The mixing of pigs, unfamiliar with one another, should be avoided whenever possible. If pigs have to be mixed, this should be done at as young an age as possible, preferably before weaning. When pigs are mixed, they should have adequate opportunities to escape and hide from other pigs.

21. The use of tranquillizing drugs, such as Azaperone and Amperozide, can be useful in order to reduce the immediate aggression and stress caused by mixing. However, their effects are limited in time, to a few hours at most, and when their effects stop, the mixed pigs often engage in agonistic interactions of the same magnitude as untreated groups.

22. Pigs which have been treated with tranquillizers at mixing do not differ from untreated pigs with regard to growth rate and performance as a whole.

23. Recommendation: The use of tranquillizing drugs in order to facilitate mixing should be limited to exceptional conditions and never be a routine treatment.

4.3 Light, climate and noise

The mainly nocturnal habit of modern wild boar is probably a consequence of hunting (Hafez and Signoret 1969). In fact, the undisturbed diurnal rhythm of captive breeds is probably not changed from that of this wild ancestors, and we can observe that pigs are mainly diurnal/crepuscolar animals. The pig possesses an eye whose dimensions are comparable to those of humans, as well as having the same apparent hypermetropia value, i.e. the same ability to see in distance; consequently, pigs probably have good visual sight capability (Piggins 1992). Although it is very difficult to ascertain whether and how animal species see colours (Piggins 1992), using operant discrimination Tanida *et al.* (1991) ascertained that weaned piglets are able to detect only blue among the three primary colours, and may not be able to perceive all wavelengths.

Simonsen (1990) recorded that fattening pigs in multi-activity pens restricted most of their activities to diurnal hours, with a bimodal distribution during the morning and late afternoon hours. Similarly, the light-darkness rhythm of 16 hours of light (05:00 to 21:00 h) and 8 hours of dark has effects on feeding, causing 2 peaks of feeding activity: one when the light turns on and another just before it turns off. Furthermore, most feed consumption was shifted to the coldest periods of the diurnal thermic cycle (early morning and late afternoon) (Feddes *et al.* 1989).

Light intensity does not seem to be a variable of great importance affecting the welfare of pigs. Van Putten (1980) was unable to prove experimentally that the behavioural repertoire of pigs, and indirectly their welfare, is affected by the presence or absence of light, although farmers have the tendency to state without hesitation that it is better to breed pigs in darkness in order to keep them calm and to avoid aggression. Nevertheless, tail biting was found to decrease greatly when, apart from other variables, pigs were maintained in a warm environment and in low light (van Putten 1968), and aggression among unfamiliar recently grouped individuals is also greatly reduced when they are in darkness (Barnett *et al.* 1994).

Young pigs, trained to perform an operant response to obtain brief periods of illumination of their pen, kept the light on surprisingly only for 0.5% of the available time (Baldwin and Meese 1977). In another study (Baldwin and Start 1985) young pigs of 8 to 12 weeks, kept in light-proof pens and trained to break an infrared beam switch with their snout to obtain periods of 40 s of illumination, turned the light on only for 1.5-2 hours during the 24 hour period. In addition, the rewarding properties of light onset did not wane during a 10-day period, showing that the operant interruption of the beam was not caused by novelty. It is worth noting that light was mainly turned on at feeding times but very rarely during the night (22.00 to 7.00 h). By contrast, pigs kept in continuous light were not motivated at all to operate the beam switch to obtain the same 40 s periods of darkness, because the total time of light over the 24 hours amounted to a mean duration of about 30 minutes. This would suggest that the domestic pig is not disturbed by remaining in continuous light as much as when it is kept in the dark.

Van Putten and Elshof (1983) stated that the welfare of pigs kept at a very low level of environmental illumination (less than 0.2 lux) is reduced. When pigs were allowed to move freely between two light-proof pens one of which was illuminated only by 0.1 lux (i.e. virtual darkness) and the other by 60 lux, there was no difference between time spent in either pen over a period of 8 days (van Rooijen 1985). In addition, there was not any evident circadian rhythm of illumination preference; in fact, during the night the pigs stayed in the twilight pen almost the same amount of time as in the light pen (Baldwin and Meese 1977, van Rooijen 1985).

Nevertheless, pigs seem to dislike intense light. When pigs were kept in darkness and trained to operate an infrared beam to obtain 40 seconds of light, they spent 54% of their time over the 24-hour period activating an intense light lamp (110 lux), while they did so for 63% of time when the light was much less intense (10 lux).

4.3.1 Air temperature

Amongst the several environmental variables that can potentially affect the welfare of pigs, temperature is certainly the most important. The domestic pig, in contrast to most domesticated species, has very sparse thermal protection offered by hair (Craig 1981). Most insulation is given by the thick subcutaneous layer of fat. The sparse hair cover allows ready evaporation from the skin but, as swine do not sweat when exposed to heat, body cooling is based on skin wetting or wallowing.

Both young and adults can readily learn to press a button switch with their snout to obtain heat from an infrared source (Baldwin and Ingram 1967 a,b, 1968 a,b, Baldwin and Lipton 1973, Baldwin 1974, Heath 1980). The frequency of such an operant response increases as the air temperature decreases (Swiergiel and Ingram 1986). Similarly, they can learn to operate another switch that turns off a draught-creating fan or one that activates a sprinkling device when the temperature increases too much (Bray and Singletary 1948). Baldwin and Ingram (1966, 1967a) showed how the hypothalamus, and particularly the preoptic area, is responsible, if cooled, for the increase of the heat switch pressing activity. Conversely, when the preoptic area is warmed there is less tendency to seek heat, even though the air temperature falls near 0°C. Similar results are obtained with localized warming of the scrotum skin up to 42°C when pigs are exposed to cold air temperature (15°C), but the same effects are not obtained when other parts of the skin on the trunk are warmed (Swiergiel and Ingram 1987).

Pigs are well equipped with behaviour responses to cold temperature. It is well known that pigs do not seem to suffer greatly from being exposed to rain or sunshine, although they often get their skin burnt when exposed to sunshine for a long time in summer. They then need a shelter when kept outdoors. In contrast, pigs greatly dislike to remain exposed to wind and, consequently, look for a convenient shelter and, if in a group, huddle to conserve warmth. This behaviour seems to be innate, as a very few minutes after birth piglets already show the tendency to huddle (Mount 1960). Such a habit is very strong, as fattening pigs prefer to huddle during the night than to operate an infrared lamp to obtain radiant heat (Baldwin 1974). At high temperature the resting group will spread out.

Mount (1968) defined thermoneutrality as that limited range of ambient temperature over which the physiological functions are maintained with the minimum metabolic rate, and hence with the minimum of energy utilization. This concept is not restricted to the domestic pig but is typical of all endotherm vertebrate species (Willson 1984, Pough *et al.* 1996). In pig production the lower threshold, i.e. the lower critical temperature, is obviously of interest because pigs maintained at ambient temperature below thermal neutrality will have lower food conversion efficiency. Pregnant sows cannulated in order to get repeated measures of serum cortisol, had higher levels at environmental temperatures of 2 or 32°C than at 18°C (Bate and Hacker 1985). As the pig increases in size, its critical temperature decreases. Although it is difficult to generalise the thermoneutral temperature for each stage of production, it is likely to be around 34°C for newborns (which have little subcutaneous fat), 25-30°C for 4-6 kg piglets, 25°C for piglets aged 8 to 14 weeks, and 20°C for growers (Mount 1960, 1968, Baldwin and Lipton 1973, Baldwin 1979, Morrison *et al.* 1987). A deterministic model to calculate the lower critical temperature has been developed by Bruce and Clark (1979). It shows that for groups of 15 growing pigs with air velocity of 0.15 m/s, this temperature decreases progressively with a concave curve from about 15°C for 20 kg pigs kept on concrete floor to 9°C for 60 kg pigs and then increases with a convex curve to 13°C for 100 kg pigs. In animals housed on straw bedding the above values decreased by 6°C at all liveweights.

Pigs perceive their level of thermoneutrality since, if kept in cool environment, they operate the infrared heat reward at a rate which allows them to maintain the minimal metabolic level (Baldwin and Ingram 1967b). Body condition is important to determine the behavioural response to the thermal environment; cold-reared pigs have a greater thermal demand as they suffer from lesser tissue insulation than warm-reared pigs (Heath 1978, 1980). Young pigs with good nutrition operated infrared heaters less often than others maintained at the same air temperature but with lower nutrition level (Baldwin and Ingram 1968a, Swiergiel and Ingram 1986). Nevertheless, the model developed by Bruce and Clark (1979) exhibits no effect of feed level on heat production below the critical temperature.

Maintaining pigs at low temperature has both health- and behaviour-related adverse effects; the frequency of coughing, diarrhoea, and tail biting increase with temperature reduction (Sällvik and Walberg 1984, Geers *et al.* 1989). Besides, it seems that even sensitive periods exist within the growth period, particularly at the onset of the fattening period, i.e. 20-30 kg, and pigs of that size need special care.

As each lying individual animal transfers heat to the substrate, the assessment of heat loss to floors is very important. It has been shown that such heat loss affects the metabolic rate and, in turn, the feed conversion rate and growth (Kelly *et al.* 1964, Stephens and Start 1970, Stephens 1971, Versteger and van der Hel 1974). Straw supplied on the pen floor helps to maintain body temperature close to the thermoneutral zone. The preference of pigs to rest on straw and its beneficial effect on newborn piglets for conservation of body heat us well known (Mount 1967, Mentzer *et al.* 1968, Stephens 1971). Such preference has a strong adaptive value even in older pigs; they prefer to lie down for resting on a straw-bedded floor at 18-21°C, while at 25-27°C, i.e. above the thermoneutral zone, they select a bare concrete floor (Steiger *et al.* 1979, Fraser 1985) is preference gives the pigs which are below the thermoneutral zone the opportunity to move into or closer to thermoneutrality. A good supply of straw on the floor should be considered whenever the air temperature falls below the thermal neutrality value.

Air temperatures above thermoneutrality induce an increase of energy utilization to dissipate the excess heat. As the upper critical temperature is reached, the body is unable to dissipate heat fast enough to prevent body temperature increase. The behaviour response to this situation is to reduce activity, to modify lying behaviour and to seek to reduce body temperature by wallowing. As a result, the lying area within the pen is made much dirtier, especially on a solid concrete floor (McKinnon *et al.* 1989). Moreover, pigs maintained at high temperature have a decreased feed consumption and delayed return to estrus (Armstrong *et al*. 1984, Britt *et al.* 1985, Biensen *et al.* 1996).

Phillips and *co-workers* (1992) studied the effect, potentially very important from the welfare point of view, of ground temperature on leg abrasion in piglets. During sucklings piglets often develop lesions on their forelegs from repeated rubbing against the floor. Phillips and *co-workers* developed an apparatus to rub stillborn piglet leg specimens against several floor types, i.e. concrete, rubber, metal. They recorded greater damage to leg tissues on warmed floors (34°C) than on cool ones (21°C), suggesting that the frictional heat build-up combines with the floor abrasiveness. Thus, the common practice to warm piglets pen floors should be considered carefully because it may increase the severity of leg lesions.

4.3.2 Air movement

Fast movement of air is another potentially negative environmental variable affecting the welfare of pigs. They avoid wind more than other factor, e.g. rain, because of its strong chilling action. Weaning pigs exposed to cold stress suffer from health problems (Le Dividich and Herpin 1994) and when exposed to unpredictable draught are more restless. The provision of solid partitions reduces local air movement and helps to induce pigs to lie down in the desired resting area (Fritschen 1975). In turn, this contributes to localise the dunging area in the pen sector far from the resting area. Unpredictable and uncontrollable air movements should be considered as stress factors, as they have detrimental effects on the behaviour of the animals (Schaepens *et al.* 1991). The chilling effect of draught is greater for young/small pigs than for adult/large ones, since the former have unfavourable body volume/surface ratio.

Wind speed of 0.05 m/s produces a forced convection loss of 1°K in 25 kg pigs, while the same result is obtained with air velocity of 0.10 m/s in 60 kg pigs (Close 1981).

Sällvik and Walberg (1984) developed the concept of "chill factor", a direct expression for cooling by convection, described by the equation:

$$F = (ta-tx) * (vx*10)$$

where F is the chill factor (in W/m2), ta is the skin temperature (in °C), tx is the air temperature (in °C), and vx is the air velocity (in m/s). A particular value of the chill factor can be obtained by the variation of air temperature and air velocity. This factor is important as liveweight influences the heat production and this, in turn, influences the animal's reaction to the climatic environment. Sällvik and Walberg (1984) showed that the optimum chill factor varied between 60 to 80 W/m2 to get the best response for several parameters, such as short laying time in the dunging area, low incidence of tail-biting, good pen hygiene, and high daily gain; the data are summarized in Table 4.3.1.

Table 4.3.1. The chill factor obtained by combinations of air temperature and air velocity (From Sällvik and Walberg 1984)

Chill factor (W/m2)		60			80	
Body Weight (kg)	50	70	90	50	70	90
Temperature (°C)			Air velocity (m/s)			
12	0.10	0.11	0.13	0.17	0.19	0.22
16	0.14	0.16	0.18	0.25	0.28	0.33
20	0.21	0.25	0.30	0.38	0.44	0.53
24	0.33	0.40	0.50	0.50	0.71	0.89
28	0.64	0.74	1.00	1.14	1.31	1.78

As with results discussed previously, free-ranging pigs kept on a restricted feeding regime tolerated high air movement more than others fed *ad libitum* (Ingram and Legge 1970). However, there was no difference in the selection of the temperature of the resting area. The same occurs in intensively bred individuals. During hot summer weather resting pigs lie down with the snout facing wind (Hafez and Signoret 1969) but the opposite orientation is adopted in a cool draught: individuals lie down with their tail facing wind, suggesting that this position reduces heat loss (Close *et al*. 1981). Aversive draught is fought behaviourally; piglets weaned at 28 days are restless with at least moderate direct draught and respond with huddling, a typical response to body cooling, or, when possible, lying down against a solid side of the pen. Alternatively, the food trough is used as barrier against draughts (McInnes and Blackshaw 1984). Weaning pigs housed at 24°C but with high air velocity (0.4 m/s) showed reduction of daily weight gain (Riskowski and Bundy 1990). Analysing the response of both growing and finishing pigs housed in groups of 9 per pen, Sällvik and Walberg (1984) detected that the preferred incoming air direction is reached when the draught is directed vertically downwards towards the dunging area. Thus, when fans above pens are used, great care should be taken in avoiding the direction of air towards the pigs, particularly if they are young.

Geers *et al*. (1986) also showed how, in growing pigs the control of the air and floor temperature can help to maintain the preferred comfort zone. When the floor temperature is higher than that of air (14-25°C) pigs prefer a lying area with air velocity of 0.3 m/s, while they did not stay on floors whose temperature is lower than air temperature. In the former context no dirty lying areas were recorded and it was concluded that to achieve this it is necessary to control air temperature and velocity as well as floor temperature. Young piglets behave similarly: four-weeks old pigs preferred to spend the night lying on a surface with low air velocity (0.15 m/s) and huddling as a response to the decreasing body temperature.

4.3.3 Air quality

Ventilation of the pig housing is very important and useful from points of view other than temperature regulation. Frequent air exchange may positively affect the relative humidity (which will be discussed below), the concentration of potentially toxic gases, e.g. CO_2 and NH_3, and above all the quantity of dust in the local atmosphere. The latter factor must be carefully evaluated because a dusty, dry environment may easily lead to irritability and aggression (Smith and Penny 1981). There are several constituents of airborne particles, whose concentration has been measured in the range of 104 to 109/m3 or a weight range of 3 to 22 mg/m3 (Robertson 1994, Hartung 1994) within a standard piggery. Most of the mass of these particles contains dust from feed (e.g. grain dust, growth promoters) but also aerosol of feed residues, urine, faeces, skin squames, grain mites, parts of insects, particles of bedding, pollen, yeasts, fungi and bacteria, mainly staphylococci and streptococci.

It is then easily understood that a high quality of air suspended dust is a cause of respiratory problems in the pigs, and also in stockpersons (Gordon 1963 a,b, Donham *et al.* 1989, Hartung 1994). High levels of dust favour the introduction of microorganisms or noxion gases into the respiratory tract, leading to reduced resistance, particularly in those animals housed in unfavourable climatic conditions (Parry *et al.* 1987, Hartung 1994). Inhalation of large amounts of dust causes overloading of the clearance mechanisms in the respiratory tract and mechanical irritation, with consequent potential beginning of infections. The size of particles is very important, as the depth of the point of deposition in the respiratory tract is inversely proportional to the particle's diameter; dust particles with diameter less than 7 µm are alveole-accessible (Henschler 1990) and then particularly dangerous. High levels of dust have a general performance-reducing effect; dust removal practised only in the farrowing house for the first 20 days post-partum led the pigs to reach market weight up to 8 days earlier than controls (Carpenter *et al.* 1986).

Bad ventilation systems will cause draughts in some parts of the pen and at the same time, stagnant areas in some corners, with deposition of large amounts of dust. Nevertheless, increased air velocity will delay particle sedimentation, which is one of the principal dust removal mechanisms. Thus, exhaust ventilation appears to be the best way to remove airborne dust (Robertson 1994).

One technique to limit the presence of dust as airborne particles is to enhance its deposition by producing ionization of the air within the building. Jensen and Curtis (1976) produced air ionization above pens containing 16 or 32 pigs from start to 55 kg, or 8 or 16 pigs from 55 to 90 kg. These groups were kept in two comparable buildings. Commercial negative-air-ionization devices consisting of electron-dispersion units that were maintained at 20,000 V ca and drew about 1 µA of electrical current were suspended above the pens of one building. The activity of these dispersion units led to very strong electrostatic particle precipitation within the ionized environment with marked accumulation of dust particles on undisturbed surfaces. These authors did not find any statistical difference in weight gain, feed consumption, disease frequency, and behaviour patterns between the two treatments. Nevertheless, we must consider that the study was carried out in two short periods in successive years, i.e. from July or August to November. Nothing is known about the long-term effects of air ionization per se and on pigs of smaller age, although an effect possibly exists; in fact, it was previously shown that ionized environments could reduce airborne dust and airborne bacteria by 2/3 and 1/3 respectively (Curtis 1972).

Gaseous ammonia is another source of increased severity of respiratory problems, in pigs as well as in stockpersons (Donham *et al*. 1989). Dietary nitrogen is the primary source of ammonia and other substances containing volatile nitrogen. Gaseous ammonia is the end product of the degradation of nitrogen and is excreted through the kidney as urea. Most of urea is located in the urine while the faeces contain urease enzyme, which breaks down the urea to ammonium.
Ammonia is detectable by the human nose at a concentration of 5 ppm and registered as a strong odour at 10 ppm. Concentrations around 25 ppm cause immediate and prolonged irritation to the eyes and to the upper respiratory tract. It is therefore recommended to limit the gaseous concentration of ammonia to a maximum of 10 ppm. The presence of ammonia sums its adverse effects to those of dust, causing

diseases to pigs. Individual and group housed piglets exposed experimentally to a range of treatments including 50 ppm ammonia and 5 mg/m3 of airborne dust showed, when euthanized at 42 days of age, snout distortion at a degree proportional to the ammonia exposure (Hamilton *et al.* 1993). Exposure to relatively high levels of ammonia (around 9 ppm) are responsible for atrophic rhinitis in group housed fattening pigs (Baekbo 1990).

When given a choice between several compartments of a large pen, each with different experimentally regulated concentrations of ammonia (varying between 0 to 40 ppm) groups of 4 pigs between 30 to 60 kg spent a greater proportion of their time in unpolluted compartments than in the others (Jones *et al.* 1996). Such an aversion was not immediate but developed after about 30 minutes. It was probably not caused by the gaseous ammonia smell but by a sense of malaise developed during the stay in such polluted atmosphere.

4.3.4 Humidity

The pig is more adapted to live in humid conditions than in a dry atmosphere. In fact a dry environment can be a cause of irritability (Smith and Penny 1981) and humid or frequently wet skin is fundamental for thermoregulation. When relative humidity is very high, the pigs become more dependent on water loss from skin, even though the respiration rate increases. This leads to the necessity to wallow or to lie on a wetted floor (Close 1981). Intensively bred piglets in the tropics, as in Ghana, are more active in hot afternoons (12:00 to 16:00 h) than in mornings (08:00 to 12:00 h), when air is cooler (Kabuga and Annor 1992).

There are no studies indicating the optimal range of relative humidity for pigs kept indoors, Bogner (1982) suggested air humidity be kept between 50% to 80%, but did not support these values with experimental data. A moderately high level of humidity is nevertheless necessary for keeping the respiratory system in good condition. In fact, the incidence of respiratory diseases is greatly reduced by maintaining pigs in a very humid environment (Gordon 1963 a,b). A dry atmosphere increases skin evaporation and consequent lowering of skin temperature, which is harmful for pigs because it removes them from the thermoneutral zone.

4.3.5 Noise

High levels of noise are potential stressors to pigs. Their origin can be identified as from the animals and from the environment. In the former case, it goes back mainly to the high number of animals housed in the same building, which produce a great amount of noise, especially at feeding times when the pigs are particularly excited and easily aggressive, and in the farrowing house, when piglets produce characteristic sounds of high frequency. High intensity sounds can be also produced by ventilation systems, which are often working for a long time intermittently during the whole 24-hours period, by feeders, compressors, etc. As the use of these devices has become very common and is almost indispensable in modern intensive husbandry (Algers *et al.* 1978a) their impact to the welfare of pigs must be carefully evaluated, as high levels of noise have been reported to be detrimental to health of farm animals (Algers *et al.* 1978b). Unfortunately, very few studies have been carried out on this topic and consequently our knowledge of the effect of noise on animal welfare is very poor.

Noise is an important stimulus in the pig's environment; for instance, it is widely used in communication even a few days after birth, when the sow signals the forthcoming lactation episode with repeated gruntings. This communication system is very strong, as the sound of a suckling litter and dam are very effective in stimulation recently weaned piglets to feed in the early days after weaning (Csermely and Wood-Gush 1981, Gonyou 1987).

It must be also taken into account that pigs, as well as other farm animal species, perceive ultrasounds at least when at short distance from the emitting source. Algers (1984) noted how 10-day-old piglets show immediate attention and orientation reaction for about 10 seconds to an ultrasound source. Similarly, 6-week-old pigs activate immediately and orientate their body toward the source, but after a few seconds that reaction fades away completely and the pigs are totally indifferent.

Algers and Jensen (1985) found that continuous loud noise (85 dB [A])of fans negatively affected the frequency of piglets massaging the dam's udder both before and after milk letdown. Moreover, they recorded lower teat stimulation by piglets exposed to continuous loud noise produced by fans and the sow produced less milk (Algers and Jensen 1991). Finally, pigs in an open field arena increase their heart rate and display attentive behaviour when exposed to high frequency (from 500 Hz to 8000 Hz) and/or high intensity (from 80 dB [Lin] to 95 dB [Lin]) sounds (Spensley *et al.* 1994, Talling *et al.* 1996) showing that acute and strong noises activate pigs' defence mechanisms and cause alarm in them.

4.3.6 Conclusions

24. Pigs do not work hard to remain in light, although prefer to have light when feeding. Some normal behaviour of the pigs (e.g. exploration) requires that light should be on for longer than the feeding period. Proper lighting is also necessary to facilitate inspection.

25. Recommendation: Pigs should never be kept in environments with constant darkness. It is not acceptable to provide light only during brief periods, for example feeding and inspection. Cycles of light and dark should be used so that the pigs have ample opportunities to carry out their normal behaviour and dark periods are provided during the resting time of the pigs, i.e. during night. It seems reasonable to provide a light period of approximately 8 hours or more each day. Minimum light intensities should allow pigs to see well enough to distinguish small objects and subtle visual signals, and should allow for adequate visual inspection. Light levels of 40-80 lux are sufficient to allow this.

26. The thermoneutral zone of a pig varies with its age, size and nutritional status, and with other environmental variables, such as draught. The welfare of a pig is best when it has access to an environment where the ambient temperature is within its thermoneutral zone.

27. Recommendation: Every effort should be made to provide pigs with an area in which they can maintain thermal comfort. When pigs are kept outside in areas without natural shelter or shade, some form of protection from the weather and from sunshine should be provided. In hot weather, pigs kept outside should have access to a source of evaporative cooling such as a wallow, although care would then be needed to minimise disease risk.

28. Dusty environments and high concentrations of ammonia and other irritating gases cause harmful effects on the respiratory system. Dry air too can be an irritating factor, increasing skin evaporation and lowering skin temperature.

29. Recommendation: Recommended maximum levels for noxious gases are: ammonia 10 ppm, carbon dioxide 3000 ppm, carbon monoxide 10 ppm, hydrogen sulphide 0.5 ppm. Pigs should be maintained in a moderately high humidity and very high dust levels should be avoided.

30. High levels of noise can be generated by mechanical devices or the animals themselves, and are associated with signs of poorer welfare.

31. Recommendation: Continuous noise in pig houses should be kept low and continuous noise levels as loud as 85 dBA should be avoided.

4.4 Space

Intensive housing of pigs, as well as of other species, developed to make efficient use of the available space with considerable reduction of the individual's living space. Since the animal's available space in a crowded pen is obviously much smaller than in extensive contexts, great attention must be paid to allow the individual to have a minimum area for its needs. The spatial requirement of each animal is then a limiting factor for intensive breeding (Bogner 1982). This chapter will show in its first part, the effects of density and/or reduction of available space on both the behaviour and physiology of the pig. The second part will deal with the agonistic behaviour caused by small available space and the minimal space requirements in relation to different body sizes.

There are both qualitative and quantitative spatial needs (Box 1973, Petherick 1983). The former are connected with the possibility to perform normally activities such as eating, exploring, social interactions, or, when necessary, withdraw from penmates and remove themselves from visual contact with others (McGlone and Curtis 1985). Thus, it is necessary to give each animal the possibility not to be in continuous physical contact with penmates and to have a minimum "empty" area around its body, if wished. Such a small area includes the space required by the animal to perform its basic movements and behaviour patterns. It is responsible for the so-called "individual distance" (Hediger 1941, 1955), which is the minimum distance within which an approaching animal elicits attacks or, rarely, avoidance. It then works as an invisible, but recognizable, micro-territory (personal space) and, like the "usual" territory, it is defended against intrusion of conspecifics. Sometimes the term "social space" is used as a synonym.

4.4.1 Crowding

Broom (1981) lists 5 advantages for the animal of maintaining an individual distance due to reduction of: (1) damage to the body due to physical contact, (2) interference and competition at feeding, (3) impedence when starting to flee, (4) disease or parasite transmission, (5) chance of rape. The amount of individual distance varies greatly according to activity and crowding. In pigs and other farm animals, usually forced to live in dense groups, the distance is compressed and very often it remains just as a small spatial sphere around the head (Fraser and Broom 1990). Repeated intrusion or long-term loss of this sphere increases the frequency of aggressive retaliations within the confined group, and the more crowded the pen, the higher is the likelihood of intrusion in the personal space. Thus, the crowding concept is crucial in intensive housing. Crowding can be explained as the movement or activity restriction caused by the physical presence of other individuals (Fraser and Broom 1990). Myers *et al*. (1971) outlined that group size (number of animals), density (number of animals per unit space), social space (the reaction of the animal to the penmates) and the space itself, are all variables involved in the concept of crowding.

Consequences of crowding have been particularly studied in laboratory rodents and consist of a sharp decline in reproduction, increased infant mortality, increase in aggressiveness, breakdown of usual social behaviour, increase in adrenal activity, decrease of gonadal activity in males (e.g. Christian 1955, 1963, Bronson and Eleftheriou 1963). In addition, some individuals no longer involve themselves in social encounters and not all the individuals of the population (i.e. only the strongest) are able to breed and survive (Myers *et al*. 1971). These effects are all produced, more or less directly by the high long-term incidence of aggression induced by crowding (and the repeated intrusion beyond the limit of the individual distance). Thus, crowding has to be considered as a true stressor.

The term "space allocation" means the surface area available for each individual animal (m^2/animal); the term "stocking density" means the number of individuals allocated in a given surface area (no. animals/ m^2). These terms are perfectly equivalent from the mathematical point of view, but it must be borne in mind that they are not so from the behavioural point of view. In fact, an animal will less likely suffer from crowding when stocked within a very large group even though maintained with constant space allocation. As with the above rodent discussed previously, intensively bred pigs also suffer from crowding; in fact, it is possible to observe among them the same stress-induced physiological and behavioural alterations. However, it must be pointed out that crowding (or even over-crowding) *per se* can have no adverse effects provided that there are plenty of resources such as food, shelter sites, etc. (Fraser and Broom 1990). It is then necessary to consider also the quality of space where the animal lives (Box 1973).

4.4.2 Space allocation

Crowding or limited available space has been shown to have adverse effects, firstly on the amount of agonistic interactions (Ewbank and Bryant 1972). Pigs penned individually show better growth rate than pigs housed in groups (Gehlbach *et al*. 1966, Hanrahan 1984, Patterson 1985, Petherick *et al*. 1989). Arranging pigs in groups of 8, 12 or 16 at constant density of 0.36 m^2/pig resulted in slower weight gain than among groups with double space allocation and group size reduced to one-half (Gehlbach *et al*. 1966). They also noted that air temperature affected the rate of weight gain and concluded that an enlargement of the minimum space requirement must be taken into account when temperature increases. A density of about 0.5-0.6 m^2/pig decreased resting time and increased feeding time, although this was not necessarily connected with increased food intake (Bryant and Ewbank 1974, Syme and Syme 1979, Brumm and Miller 1996). Similarly, Jensen (1984) noted how pregnant sows housed in groups of four with 2.27 m^2/sow had insufficient space to develop a fairly stable social system.

Pickett *et al*. (1969) confined groups of 10 or 20 pigs in 11 m^2 pens and recorded lower weight gain in the more dense groups, although the food conversion efficiency was the same, as well as higher incidence of esophago-gastric ulcerations. Similar decrease in weight gain in larger groups has been recorded by Bryant (1970), Jensen and Curtis (1976) and Zin (1980). Weaned 6-week-old piglets housed at 0.5, 1.1, 1.7 or 2.3 m^2/pig showed better weight gain and feed conversion efficiency when in the first 3 space allocation pens than when in the fourth pen size, indicating that space allowance beyond 1.7 m^2/pig is not beneficial (Beattie *et al* 1996), whereas Brumm (1996) recorded a linear improvement in the average daily gain with increasing space allowance in barrows housed at 0.65, 0.93 or 1.20 m^2/pig at the initial weight of 55.5 kg.

Pigs allocated in groups of 8, 16 or 32 individuals in constant pen size showed the frequency of tail-biting to be directly correlated with crowding (Madsen *et al*. 1976). Similarly, several papers reported major decrease in resting time correlated with large group size (Ewbank and Bryant 1969, Ross and Curtis 1976, Randolph *et al*. 1981); if we consider that the pig is biologically structured for daily long periods of rest or inactivity (Hafez and Signoret 1969, Ruckbusch 1972, Fraser and Broom 1990, Tober 1996) this restless can be of concern for welfare. Tober (1996) stated that multiparous sows need more space for suitable resting accommodation than primiparous ones (minimum of 1.3 m^2/sow vs 0.95 m^2/sow).

While Jensen *et al*. (1966) did not find any improvement in performance by increasing the available space for starter pigs from 0.28 to 0.35 m^2, Randolph *et al*. (1981) noted a significantly better growth rate for similar pigs by increasing their space allowance from 0.33 to 0.66 m^2/pig, whereas Brumm and Miller (1996) noted the same effect when increasing space allowance from 0.56 to 0.78 m^2/pig. Heitman *et al*. (1961) varied both density and group size. They allocated groups of 3, 6 and 12 pigs in three types of density conditions: 0.45, 0.90 and 1.80 m^2/pig. The results showed better food intake, weight gain and feed conversion efficiency for pigs housed at the lowest density and in smallest group size. Similar results were obtained by Brumm (1996) and by Spicer and Aherne (1987) who noted that weaned pigs had better growth and spent more time feeding when penned in groups of two rather than in groups of four.
On the other hand, pen shape does not seem to be as important as its size. Wiegand and co-workers (1994) observed the behaviour of 100 kg pigs housed in differently shaped pens (rectangular, triangular, elliptical, round and square) with space allowance of 0.58 or 0.65 m^2/pig. They noted minor behavioural differences between type of pen shape but no difference in performance. However, pigs in smaller pens, regarding their shape, showed more threats, prolonged general activity and standing.

4.4.3 Physiological effects

Limited available space has also been found to have adverse effects from the physiological point of view. For instance, the poorer growth rate and food conversion recorded in young pigs with reduced space allowance seems to indicate a chronic stress response with negative effects on the balance of nitrogen (Mayer and Rosen 1977, Hemsworth *et al*. 1981). Hemsworth *et al*. (1986) recorded the plasma free-corticosteroid concentrations in groups of 6 gilts about the size of mature gilts and first-litter sows, housed in pens with space allowance of 1, 2 or 3 m^2/gilt. There was a significant increase in plasma free-corticosteroid concentration in 1- m^2 gilts, while the amount of general activity did not differ between treatments. Thus, such a hormonal difference was probably a direct consequence of crowding. The sustained elevation of free-corticosteroids is indicative of a chronic stress response, with consequent welfare reduction (Barnett *et al*. 1984). The elevation was a consequence of an increase in total corticosteroid concentrations as well as a decrease in the maximum corticosteroid binding capacity.

Moreover, the 1- m^2 space allowance gilts showed a lower mating rate, i.e. a lower percentage of gilts detected in oestrus, which probably resulted from an increase in undetected oestrus frequency rather than a complete failure to ovulate. This result also is indicative of chronic stress in restricted pigs due to crowding, similar to the observation that experimental administration of corticosteroids, ACTH or synthetic glucocorticoids interfere with ovulation in gilts and sows (Esbenshade *et al*. 1983, Paterson *et al*. 1983). Similarly, post-pubertal gilts housed in large groups causing a reduction of space allowance to less than 0.9 m^2/gilt showed an increase of undetected oestrus from 3.8 to 8.0% (Cronin *et al*. 1983).

Space restrictions affect farrowing sows as well; their consequences are discussed in detail in chapter 5.3.

4.4.4 Feeding space

Space allowed for feeding, if grouped pigs are fed on ration basis, is important as a potential source of aggression and then poor conversion efficiency (Ewbank and Bryant 1969). Piglets weaned at about 4 weeks are generally fed *ad libitum* and Sainsbury (1963) recommended allowing pigs with not less than 0.15 m/pig along the trough, taking into account the marked tendency of weaned piglets to show allomimetic behaviours and then to co-ordinate their activity. Blackshaw (1981) made an attempt to verify such space allowance. She allocated groups of 9 pigs, weaned at 24-29 days, in pens containing 1 x 0.16 x 0.14 m troughs, providing an allowance of 0.11 m/pig (i.e. 27% smaller than the space suggested by Sainsbury [1963]). The lying and feeding behaviour of piglets were recorded during 24-h periods. At no time did all pigs from any group fed together and a very small percentage of scans revealed six or more pigs feeding together. There was very limited competition for feeding space at the trough and Blackshaw (1981) concluded that trough space providing 0.11 m/pig was adequate, as piglets occupied only about 70% of the available trough space.

A different situation is found when pigs are not fed *ad libitum*. In fact, in a study carried out on grouped pregnant sows after their 80th day of pregnancy and fed twice a day with about 1 kg/sow of mash (Csermely and Wood-Gush 1990a), the feeding area available to each sow was greatly influenced by social rank. At feeding times the allocation of mash dropped out from the feeders suspended above the pen floor, making a pile of about 6 m^2. The fifteen sows of the group had then the possibility to approach the mash pile feeding together in that restricted area (about 0.4 m^2/sow). Although the study did not attempt to provide any detailed calculation of the floor area used by the sow, it showed that dominant sows fed on a wider, central, and more thick area of the pile, forcing, with physical attacks and threats the subordinates to withdraw and to feed at the boundaries of the pile. In a similar context, Brouns and Edwards (1994) ascertained that low-ranking sows achieved less weight gain than high-ranking ones when floor fed a restricted ration, but that this did not occur when sows were fed *ad libitum*.

Since feeding free-ranging or outdoor pigs show very few interactions because they are spaced out (Jensen and Wood-Gush 1984, Martin and Edwards 1994) the high level of competition recorded in Csermely and Wood-Gush's study is clearly a result of the limited space available by the sows. Csermely and Wood-Gush (1990a) then suggest that, when pigs are not fed *ad libitum*, the method of dividing the same amount of food in scattered smaller piles would likely reduce the attacking tendency of high ranking sows. However, if free-ranging sows have a restricted feeding space, there is an increase of competition among the group, which leads subordinates to be excluded from feeding by dominant sows (Signoret *et al*. 1995).

4.4.5 Agonistic behaviour

Crowding, little available space and feeding or trough competition lead invariably to arise in aggression among penmates. Ewbank and Bryant (1969) noted how, with small available area (0.65 or 0.84 m^2/pig), there was a rise in the severity of social encounters, particularly at the feeder, although the overall frequency did not change. They concluded that high stocking rates cause the dominance hierarchy to be less successful in controlling aggression within grouped pigs, and this could account for the differences in performance between groups housed at different densities.

The available space seems to alter even the development of behaviour, as shown by the agonistic behaviour of piglets reared during their first 8 weeks of age in groups of 7-9 in pens at 0.4-0.5 m^2/pig, which was clearly less developed than that of piglets reared in pens with an available area of 0.7-0.95 m^2/pig or 3.1-4.0 m^2/pig (Lammers and Schouten 1985a). In fact, piglets reared at higher density did not develop threatening behaviour patterns and did not learn to place the head-knocks exclusively on the head and shoulders of the opponent penmate. It is also possible that the whole social hierarchy cannot develop completely and the piglets reared with such space allowance then show infantile fighting even when older. Lammers and Schouten (1985a) therefore conclude that, in order to allow the development of normal agonistic behaviour, it is very important that the pens where piglets are reared from birth allow an available space of greater than 0.5 m^2 per individual. Moreover, such effects are maintained with time; 10-week-old pigs reared in small pens were more likely to perform abnormal agonistic behaviour. In experimental social encounters between two pigs, submissive pigs appeared to be more afraid of a dominant one reared in small available space pens than of another reared with more space, mainly because of its altered agonistic behaviour (Lammers and Schouten 1985b).

4.4.6 Body size and spatial requirements

The pig's body size dimensions are the primary determinants of its static space requirements. This is important from the welfare point of view since an animal needs a minimum amount of space to perform a certain behaviour pattern and, if that space is not allowed, the pattern will be suppressed or displaced, with consequent rise of abnormal behaviours, physiological changes and expected reduction on performance (Petherick 1983).

We can be confident that the pig maintains the same body shape during its growth, with only minor changes. The liveweight can then be expressed as function of body dimensions, and vice versa, with the following equations:

(1) $W = kL^3$ or (2) $L = kW^{1/3}$

where W is the live weight, L is the body dimension and k is a numeric constant. From equation (1) (Petherick 1983), we can understand that it is possible to obtain the weight by simply measuring the body dimension. The superficial dimensions derive from those equations and can be expressed as:

(3) $A = kW^{2/3}$

where A is the surface area occupied, whose values vary as function of the type of lying shown by the animal, i.e. recumbent or on the sternum. More recently, Edwards *et al*. (1988) and Spoolder *et al*. (1997) proposed a mean value of $0.030*W^{0.67}$ to optimize performance on slats.

In order to allow the pigs to have the most comfortable environment, their behavioural repertoire must be fully performed. One basic requirement concerns the possibility for grouped pigs to rest all at any one time, and this is the parameter determining the total space allocation in intensive husbandry (cf. Brambell 1965, Sainsbury 1967). The way pigs lie on the ground is known to be influenced by several environmental, social and pen design variables, which are discussed elsewhere in this report. The best study aiming to estimate the spatial needs was carried out by Petherick and Baxter (1981). They developed a model that can be used for a number of housing designs over several types of body weights. They also developed two diagrams ("pigtographs") depicting the floor area occupied by a side recumbent pig or a sternal recumbent one. Both pigtographs were based on equations for body sizes of length ($0.300*W^{0.33}$), height ($0.156*W^{0.33}$) and breadth ($0.064*W^{0.33}$), expressed as function of body weight (W). Thus, the equations lead to a minimal occupied area of $0.047*W^{0.67}$ per pig for side recumbency and $0.019*W^{0.67}$ for sternal recumbency.

The equations for both types of recumbency are useful because they can describe the space used by pigs in a hot climate and cool climate respectively, since the type of lying down posture adopted by pigs outside their thermoneutral zone is function of the necessity either to dissipate excessive heat or to limit such loss. Additional space must be taken into account to allow movements of transition from one posture to another (e.g. from lying to standing or vice versa) (Baxter and Schwaller 1983). Besides, it must be considered that when pigs are group-housed at low air temperature they tend to perform sternal recumbency and then all individuals are allowed to do so. In contrast, with warm or hot air temperature it is possible that not all group members can lie down on their side together, because the total area encompassed may be insufficient for accommodating them and the extra space needed for transitional movements.

Petherick and Baxter (1981) reported a diagram plotting the curves of the presumed lying area (in m^2/pig) against the live weight for both side recumbency and sternal recumbency (Figure 4.4.1). In addition, Petherick and Baxter (1981) developed a diagram which plots the space allocation values (in m^2/pig) against body weight (expressed as $kg^{0.67}$), again for both side recumbency and sternal recumbency) (Figure 4.4.2). A similar diagram was developed by Edwards *et al.* (1988) who drew a space allocation curve without considering lying type against liveweight expressed in kg (Figure 4.4.3). These diagrams can be used a basis for recommendations for the minimal space allowance for acceptable welfare.

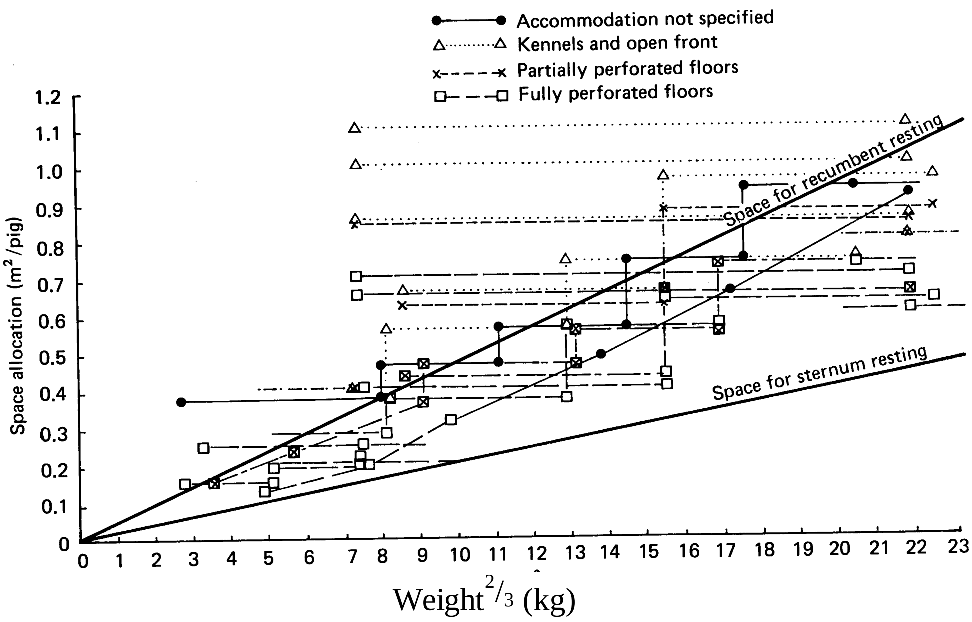


Fig 4.4.1. Recommendations for space allocations (Petherick, 1983)

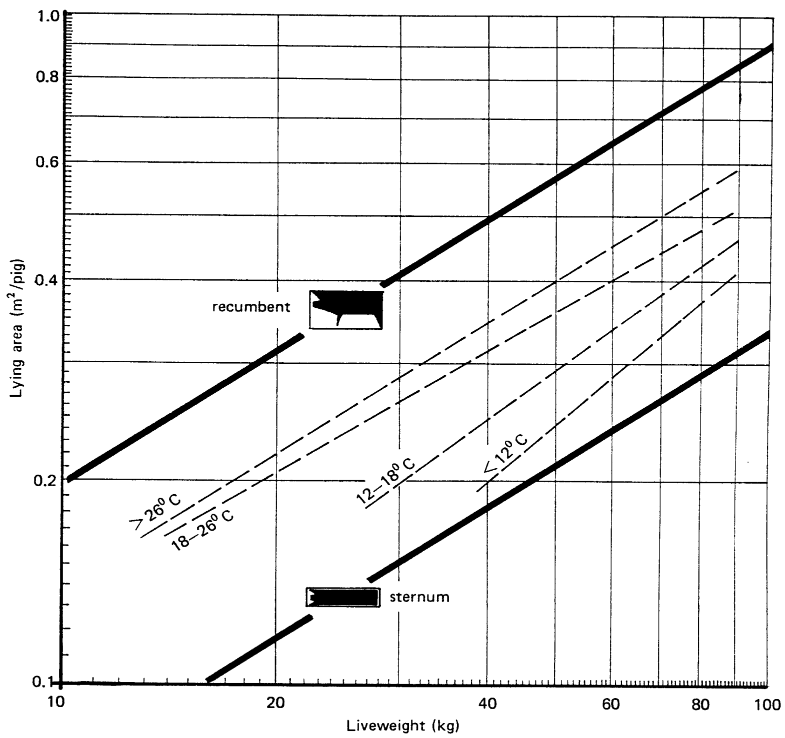


Fig 4.4.2. Relationship between floor area occupied by resting pigs and air temperature (Petherick, 1983).

The model developed by Petherick and Baxter (1981) is also useful for understanding some puzzling incongruence between results reported by other studies (see Petherick 1983 for details) about why some experimental treatments produced or not differences in productivity. In fact, no differences are expected when treatment allocations are above the necessary space for side recumbency. Moreover, negative effects of increased group size, considered only from the static space point of view and not from others (e.g. social interactions), will be expected only when the space allocation is reduced beyond a minimum level.

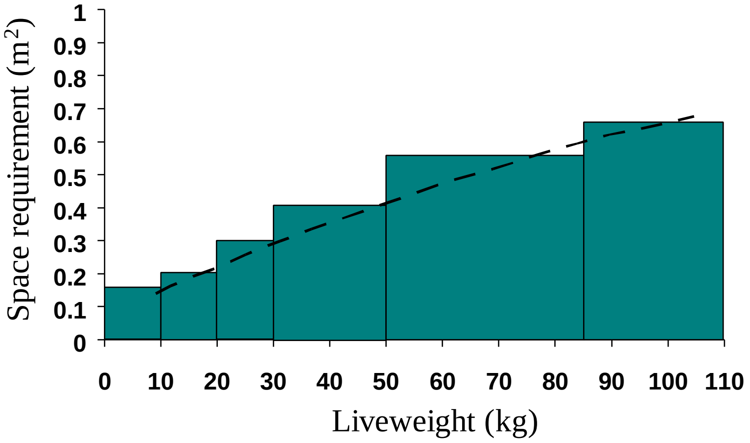


Fig 4.4.3. The relationships between stocking density and average weight of pigs per pen according to the equation $A=0.03\ W^{0.67}$ (dashed line) and according to Directive 91/630 (solid line).

4.4.7 Conclusions

32. The welfare of pigs appears to be negatively affected by strong reduction of available space and this occurs at all ages. Crowding causes negative effects on physiology, behaviour and production.

33.. The necessary space for a pig to be able to lie down in lateral recumbency can be calculated by the formula: Area (m^2)=0.047 x Liveweight $^{0.67}$. When the available space has been 0.03 x Liveweight $^{0.67}$ m² per animal, no negative effects on performance have been detected.

34. Recommendation: The space available to pigs of different categories should provide room for all pigs to lie at the same time in lateral recumbency. It should be remembered that pigs in groups, will in many conditions, be able to share the available space. Other factors such as temperature, group size and type of building will affect the actual space requiremant.

35 Lack of feeding space is a potential source of aggression and poor feed conversion. Provision of food ad libitum reduces agonistic competition at feeding times and reduces differences in food intake between individuals. Moreover, feeding *ad libitum* allows a reduction of the minimum trough space.

36. Recommendation: The minimum space (trough length) for groups of pigs fed restrictively at the same time e.g. at a single trough, should allow all animals to feed simultaneously and in any case the minimum length of the feeder should be expressed by the equation:
Length (mm) = 60 x liveweight $^{0.33}$

4.5. Surgical intervention

The nociceptive system exists in pigs as in other mammals, including man. The tissues which are normally cut in surgical interventions on farms are: during castration, the scrotum and tissues attaching the testicles, the tail in tail-docking, the teeth in tooth-clipping the ears in ear-notching and ear-tagging and the nose in nose-ringing. The skin may also be perforated for insertion of electronic devices. All of these tissues are innervated, in adult pigs and in young piglets. The presence of pain receptor cells, nerves in the nociceptive pathway and a complex brain for analysing such input means that it is very likely that the feeling of pain in young or adult pigs when such tissues are damaged is similar to that which humans would feel. The behavioural responses of pigs to the surgical interventions support this general argument. Data providing evidence for pain during surgical interventions in pigs is presented below for the various operations.

4.5.1 Castration

Castration is usually carried out on young piglets during the first few days or weeks of life by surgical means without an anaesthetic. The principal purpose of the operation is to prevent boar taint in older male pigs. It may also reduce injuries due to early development of sexual behaviour in males. The castration operation is carried out very rapidly and involves cutting and tearing of tissue during the removal of the testes. Using care during surgical castration, the tearing of tissue can be avoided.

A detailed study comparing castrated and handled but non-castrated pigs was carried out by Wemelsfelder and van Putten (1985). Piglets were castrated without anaesthetic during the fourth week, as occurs on many farms in the Netherlands. Handling itself elicits struggling and loud squealing from piglets, so the movements and vocalizations of female piglets which were handled and male piglets which were both handled and castrated were compared. The mean frequency of the scream during handling only was 3500 Hz but after the first cut during castration it was 4500 Hz and after the second cut it was 4857 Hz. Both the number of frequencies occurring in the sound and the number of changes in sound distribution over the frequency range were higher after castration. Recently castrated piglets were less active and showed more trembling, leg shaking, sliding and tail jerking; some vomited, and all initially avoided lying, then later lay in a way that appeared to spare their hindquarters. The duration of the pain was indicated by the continuation of some of these changes in behaviour for 2-3 days.

In a subsequent, somewhat similar study, Braithwaite *et al*. (1995) recorded the vocalizations of piglets, which were castrated or sham-operated, at different stages during the castration procedure. The rate of vocalisation was significantly greater in the castrated than in the sham-operated piglets during the cutting of the spermatic cords, the second scrotal incision and the application of disinfectant after the operation. During the cutting of the spermatic cords, castrated piglets produced calls of a significantly higher frequency (4483:3482 Hz), longer duration (650 v 446 ms) and greater loudness (63:55 db) than control piglets. Piglets held tightly on a bench showed a greater vocal response than piglets held by their back legs with the head down and the back towards the operator. Fraser and Broom (1990 p. 269) and Braithwaite *et al*. (1995) point out that the production of loud vocalisations by piglets which are attacked or in pain is adaptive because it will attract the attention of the mother, or possibly other pigs, and may startle the attacker. Such signalling would normally be expected to be honest in that it indicates real pain or distress in the piglet rather than being used to deceive other individuals. Hence the welfare of piglets can be evaluated as poor when they scream and worse when they scream louder and at a higher pitch.

The principal purpose of castration is an economic one and the surgical intervention does not normally result in any benefit to pig welfare. If the animals were kept to a greater age, the castrated animals might derive some benefit from the fact that there is some reduction in aggression and they could continue to be kept in groups at an age when intact boars would sometimes have to be housed individually. However, castrated males are usually slaughtered before they reach such an age. A few individuals mature early but boar taint affects few animals before a weight of 100-110 kg but in many member states of the EU, all male pigs are castrated. At present, castration causes severe pain and distress to pigs which should be avoided if possible. If castration could be carried out without the pain and distress caused by the procedure, most people would find the consequences acceptable if there are benefits to product quality or ease of management of animals. Immunocastration is one possible way to achieve this but studies of all aspects of effects on welfare should be carried out. In the meantime, pain at the time of the operation and in the days afterwards should be minimised by anaesthesia, avoidance of tearing tissue at the time of the operation, or analgesia.

4.5.2 Tail-docking

The effect of tail-docking on pigs has not been extensively investigated but it is known that pigs use their tails in communication and such usage would be considerably impaired by cutting off most of the tail The innervation of the tail and the effects of docking on its histopathology are described by Simonsen *et al*. (1991). When day-old piglets had their tails cut off, the cut end of peripheral nerves which would normally extend to the tip of the tail could be seen. In 90 kg fattening pigs with docked tails, examination of the tail stump showed that the neurofibrils were aggregated in lumps of varying thickness, myelin was unevenly distributed and there was a pronounced proliferation of Schwann cells and of fibroblasts with thickened perineural sheaths. In some cases, traumatic neuromas were encountered which had whirl-like proliferations of Schwann cells and fibroblasts, compressing and eliminating axis cylinders and myelin sheaths. It would seem from the neuroanatomy that the tail of the pig is likely to be sensitive for its entire length and behavioural responses to immersing the tail in warm water indicate that this is so (Zanella

1992). Tissues with traumatic neuromas may be very painful in man and hyperalgesia may appear during the course of regeneration in a peripheral nerve (Sunderland 1978, Thomas and Holdorff 1984). Hence the neuromas in the docked tail are likely to cause spontaneous pain to the pigs. It is also likely that the docked tail is more sensitive to touch or oral manipulation so the pig with a docked tail will respond to attempted tail-biting more rapidly than a pig with an intact tail and will thereby prevent wounding. In a further study, Simonsen (1995) reported that there was no difference in the frequency with which the tails of pigs with intact tails and the tails of pigs with docked tails were seen in the mouths of other pigs. This observation supports the suggestion that the effects of docking on the frequency of tail wounds may be a result of the increased sensitivity of the docked tail.

Tail-biting can cause serious welfare and economic problems. Tail-docking reduces these but causes short-term pain when it is carried out and long-term pain where neuromas form. A procedure which reduces the serious problems associated with tail-biting by making the tail painful to touch and painful at other times seems undesirable.

Other methods for the reduction of tail-biting exist. When pigs with intact tails are fed an adequate diet, provided with sufficient water, provided with straw or other manipulable materials, or earth for rooting, and kept at a stocking density which is not too high, tail-biting is seldom serious (van Putten 1980, Feddes and Fraser 1993, Fraser 1987 a,b, Fraser and Broom 1990 p. 327). Tail-biting is an indication of an inadequate environment and indicates that welfare is poor in the animal carrying out the biting.

4.5.3 Tooth-clipping

The teeth of piglets are usually shortened soon after birth in order that damage to the mother's udder and to other piglets is minimised. Such damage often does not occur, or if it does occur it is not serious, but occasionally there is damage to the mother which requires treatment or which affects her willingness to allow suckling.

The shortening of the pointed teeth of the piglet is usually carried out by clipping them to about half of their initial length. In some places the teeth may be ground down with a grinding machine. The clipping or grinding exposes the dentine which is innervated. No specific study of the effects of this procedure has been carried out but in many other studies of mammalian teeth, any damage which exposes dentine is painful and the pain persists for some hours or days. There is no reason to presume that piglets do not feel pain when their teeth are severely damaged. Since there is evidence that grinding teeth, even when done rapidly, causes less tooth cracking than clipping teeth (Burger 1983, Heinritziet *et al*. 1994), it is likely that there is less long term pain with grinding than with clipping.

Research on the value of tooth clipping has had mixed results. Three studies of sows and piglets kept indoors reported significant udder damage which was sometimes serious when teeth were not shortened (Perry 1970, Wilkinson and Blackshaw 1987, Brookes and Lean 1993). However in a study of 49 litters of outdoor sows, Brown *et al*. (1996) saw no damage to sows when teeth were not shortened. There was facial injury to other piglets, which was worse when piglets were fostered, but the injuries were all superficial and had no effect on piglet growth. The absence of injuries to sows and low degree of injury to piglets may be because escape is relatively easy in animals kept outdoors.

Tooth-clipping or grinding should not be carried out unless there is a substantial advantage for it. It seems unlikely that the causing of pain in every tooth of every piglet could be justified by the relatively minor advantages which occur as a consequence of the practice. However, the fact that the teeth are shorter is not likely to cause severe problems for the piglet. Hence, if the tooth-clipping could be carried out without causing pain, for example by using anaesthetic or analgesic, its use would be justified.

4.5.4 Ear-tagging, ear-notching and other identifiers

Tags and notches in the ears are used for the individual identification of pigs on farms. If tissue is removed from the ear of a pig, the pain which results is likely to be proportional to the area of the cut surface. If major structural parts of the pinna of the ear are damaged, the pain may be greater. Cuts on the ear may not heal properly, thus resulting in further pain.
Well designed ear tags cause a small area of damage to the ear. Ear notches cause a larger area of damage and would appear to be entirely unjustifiable. The insertion of electronic identifiers should be possible without much tissue damage but new developments should be monitored in this respect.

4.5.5 Nose-ringing

Rings are occasionally inserted in the noses of boars to facilitate handling and in sows and gilts to prevent them from rooting in fields. The ring is inserted into the nasal septum which is fleshy so tissue damage occurs. There is likely to be a relatively small amount of pain associated with insertion and subsequent healing. The nose tip area is highly innervated. If a nose ring was pulled it would be very painful so this should never be done. It is sufficiently painful when pushed to prevent nose-ringed sows from rooting in the ground. Rooting is a behaviour which pigs have a strong preference to perform (Hutson 1989) so there will be an adverse effect on their welfare if they are unable to root, especially when they are surrounded by stimuli which would often elicit rooting. Farmers use nose-ringing solely to protect pasture so the only advantage for welfare is that it makes the keeping of sows outdoors more viable economically.

4.5.6 Tattooing and slap-marking

Injection as a routine procedure is considered in section 4.7. The needle point marking which is involved in tattooing and slap-marking is not normally considered to be a surgical intervention although some tissue damage does occur. Slap-marking is often used to put a mark and number into the skin of pigs which will indicate the origin of carcasses after killing. Pigs show a behavioural response to the application of the slap. Whilst the extent of effect on welfare is not known, it is widely assumed to be slight.

4.5.7 Conclusions

37. Castration is carried out principally to avoid boar taint in meat but also to reduce fighting. It is not necessary if animals are slaughtered before these maturational changes occur. Castration using surgical means causes prolonged pain which is likely to be worse if there is tearing of tissues. This pain could be reduced by cutting tissue and not tearing it and by anaesthesia or analgesia. Effective anaesthesia and analgesia are possible but further information is needed on whether or not there are side effects. Further information is needed on alternate means of castration.

38. Recommendation: Castration by a means which does not involve pain and other aspects of poor welfare would be acceptable. Surgical castration should be carried out using sufficiently long acting analgesia provided that it is demonstrated that the benefits for welfare of using these are greater than any adverse effects on welfare. The tearing of tissue when the testes are removed should be avoided

unless prolonged analgesia is possible. Other new techniques would be acceptable if their net benefits for welfare outweighed any disadvantages for welfare.

39. Tail docking is likely to be painful when it is carried out and it has been demonstrated that in a proportion of animals it leads to neuroma formation and hence to prolonged pain. Damaging effects of tail-biting can be reduced by tail-docking, probably because the docked tail is very sensitive and hence more rapidly removed if taken into the mouth of another pig.

40. Recommendation: The problems of injury following tail-biting should be solved by improved management rather than by tail-docking.

41. Tooth-clipping and tooth grinding are likely to cause immediate pain and some prolonged pain. Tooth grinding causes less tooth fracture than tooth clipping. It is desirable that management systems in which tooth-grinding or tooth-clipping are not needed are designed or that pain is minimised using analgesics. Ear-tagging and ear-notching may be painful to the pigs. Nose-ringing is painful as well and affects sensitive tissue of the pigs.

42. Recommendation: Tooth-grinding rather than tooth clipping should be used but efforts should be made to avoid the necessity for either. Ear-tagging should be carried out in such a way that the area of tissue damage and resulting poor welfare are minimised and the cutting of notches, or other wounding of the ears of pigs for marking purposes, is acceptable only if the total cut area is no greater than that which would be caused by a well-designed ear tag. Nose-ringing should be avoided whenever possible and animals should never be pulled by a nose ring.

4.6. Stockmanship

The importance of research into the relationship between the stockman and his pigs was first highlighted in a study carried out in the Netherlands (Hemsworth *et al*. 1981a). Twelve commercial units, each run by a single stockman, were controlled by a large integrated company which dictated that all outside inputs (source of pigs, feed, management and veterinary advice) were similar. Despite this, the farms showed large differences in reproductive performance, with averages ranging from 17.9 to 22.5 pigs born per sow per year. To seek some explanation for this, the sows on each unit were subject to behavioural tests assessing their response to humans. It was found that sows on farms with poor reproductive performance showed more signs of fear of humans. When tested in their stalls, they had a greater withdrawal response to the approach of an experimenters hand and when confronted with a strange person in an open arena they showed less approach behaviour.

This phenomena was subsequently investigated in a series of experiments. Young pigs were subjected for periods of 5 minutes three times weekly to different handling treatments. Some pigs received regular pleasant handling, gentle stroking whenever they approached a human experimenter, whilst others received regular unpleasant handling, being given a small electric shock when approaching the experimenter. The latter treatment was shown to produce marked avoidance of humans in an experimental test and measurement of corticosteroids indicated that these animals had a chronic stress response. This was reflected in poorer growth rate and lower pregnancy rate (Hemsworth *et al.* 1981b). It is known in other species that 'sensitive periods' exist early in life during which later social relationships can be based. To see whether there was a key time at which pleasant contact with humans would influence later behaviour, piglets were treated from birth to 8 weeks of age in one of three ways (Hemsworth *et al*. 1986). Some were artificially reared in a group with regular handling, some remained on the sow for 4 weeks but received regular handling and some remained unhandled except for routine husbandry tasks. When tested in later life, the handled piglets more readily approached humans but there were no differences between sow and artificially reared. Handling also appeared to have advanced the rate of sexual development.

A longer term effect of handling quality on reproductive success in both sexes was shown in a subsequent study (Hemsworth, 1986a). From 11 weeks of age, pigs received either pleasant or aversive handling for a 5 minute period three times weekly. Control pigs were handled only as required for routine husbandry tasks. Once again, pleasantly handled animals showed faster approach behaviour and more interactions with humans than those handled unpleasantly, with minimally handled animals being intermediate. Unpleasantly handled animals had higher basal corticosteroid levels, and pleasantly handled animals did not show the same rise in cortisol when approached by a person as animals on the other treatments. Following unpleasant handling, gilts had poorer conception rate and boars had smaller testicles and took longer to develop a coordinated mating response.

The exact nature of signals from humans that pigs find friendly or aversive was investigated (Hemsworth *et al.* 1986b) by assessing the effect of different behaviour patterns on the approach behaviour of naive pigs at 2-3 months of age. Pigs more readily approached a stationary person than one walking towards them, and more readily approached someone squatting than standing upright. There were no significant effects of arm position (outstretched or retracted) but bare hands with human odour were more readily approached than gloved hands. Active interaction with the pig, as opposed to passive response to its investigation, increased approach behaviour. Repetition of a pre-recorded call in a harsh or soft voice had no effect. It was interesting to note significant differences between litters in this study. It was later demonstrated, by testing progeny from 76 different sires, that fear of humans appears to be a moderately heritable trait in gilts (Hemsworth *et al*. 1990).

Whilst the above experiments provide good evidence for benefits of pleasant handling, in any farm situation it is likely that handling may be neither consistently good or bad. To look at the consequences of inconsistent behaviour, the previously used criteria of good, bad or minimal handling were tested against a regime in which unpleasant and pleasant handling bouts were randomly applied to individually housed pigs at a ratio of 1:5 (Hemsworth *et al*. 1987). Pigs receiving the pleasant treatment approached more readily than others, and growth rate from 7-13 weeks of age was higher for the pleasant or minimally handled animals. Both unpleasantly and inconsistently handled animals had higher basal cortisol levels and greater rise in cortisol in response to approach of person, indicating that these interactions with humans resulted in both acute and chronic stress for the animals. Unpleasant experience of handling by one stockperson appears to be generalised to fearfulness of other humans (Hemsworth *et al*. 1994).

However the consistent indications emerging from this series of studies were not supported by work from other centres. Paterson and Pearce (1989) subjected pigs from 80-164 days of age to similar regimes of pleasant or unpleasant handling. At the end of this time, pleasantly handled pigs were quicker to approach a human, and interacted more quickly and more frequently with one. However there were no differences between the groups in growth rate and the time from boar exposure to puberty was actually less for those handled unpleasantly. Subsequent investigation showed no effect on structure of the adrenal glands which might indicate differential stress. They concluded that unpleasant handling did not result in chronical stress, but rendered animals more sensitive to acute stress. Because, in their study, pigs received the handling treatments as part of the group in their home pen, it is possible the results reflect a difference in susceptibility between group and individually handled gilts.

The effect of the environment in modifying handling stress was demonstrated in a subsequent study (Pearce *et al.* 1989). They looked at pigs from 40-90 kg housed in barren or enriched pens, which were handled according to the two previous treatment regimes in home the pen. Once again, pleasantly handled pigs interacted with humans more quickly and more frequently in a test situation. Pigs from enriched pens, both pleasantly and unpleasantly handled approached faster than those from barren pens. Again there were no differences in growth rate and no effect on the adrenal glands, supporting their previous view that intermittent unpleasant handling did not cause chronic stress, but made animals more sensitive to acute stress. It had been suggested from earlier work (Arone and Dantzer, 1980) that social interaction could help pigs to resist effects of other stressors.

Hemsworth and Barnett (1991) tried to finally establish the importance of group or individual housing on response to handling. They found that unpleasantly handled pigs, from both individual and group housing, had initially slower growth and poorer overall food conversion ratio than individually housed and pleasantly handled pigs. Unpleasantly handled pigs from both treatments showed signs of fearfulness but this was only slightly greater in the case of approach time for individually handled animals. Effects of handling persisted through to post mating periods after treatments stopped but were greatly reduced, possibly due to positive handling received subsequently while stockmen carried out routine tasks. No effects were seen on basal cortisol or response to ACTH, but individually housed, unpleasantly handled pigs showed greater cortisol response to humans. However no differences were detected in mating behaviour or success. Overall conclusions are still hard to draw, since a final study by Paterson and Pearce (1992) with individually housed pigs again failed to show differences in growth and corticosteroid level between pleasantly, unpleasantly and minimally handled pigs. Possible effects of other factors such as handling frequency and space allowance may be confounding direct comparisons. However there is little doubt that, in many circumstances, the behaviour, stress physiology and performance of pigs can be significantly influenced by their handling. Growth rate, feed conversion efficiency and mating success (see above) together with litter size, piglet survival and growth (Seabrook, 1991) have all been shown to be affected.

4.6.1 The training of stockmen

The demonstration that the interaction between the stockman and his pigs can have important effects for production makes it important to better understand the factors which contribute to the making of good stockman. Hemsworth *et al.* (1989) studied the relationships between the attitudinal and behavioural profiles of stockpersons and the level of fear of humans seen in their pigs. They found that the attitude of the stockman towards petting pigs, and the extent to which they mishandled pigs in their daily work, were significant predictors of the level of fear in their animals and, in turn, of the reproductive performance of those animals.

With this knowledge, it was possible to look at both selecting better stockmen and improving existing stockmen by training them in the importance of good pig handling procedures. This was tested by applying on some farms a training procedure which involved providing stockmen with information on the sensitivity of pigs to negative handling and the practical benefits in ease of management and productivity when positive handling procedures are adopted (applying a cognitive-behavioural intervention procedure). When compared with 'untrained' farms over the same period, this procedure resulted in a significant change in stockman attitudes and quality of handling, reduced fear levels in the pigs and increased performance by 5 pigs per sow per year (Hemsworth *et al*. 1992, 1994).

4.6.2. Conclusions

43. The quality of stockmanship has large effects on the welfare of pigs in any housing system. A skilful stockman can compensate for many bad effects of certain housing systems and a poor stockman cause problems in an otherwise good system.

44. Recommendation: Every person who is in charge of pigs should be licensed for this occupation. Such licensing should follow proper training and certification.

4.7 Disease prevention

During the last decades the emphasis has been on genetics and on nutrition to achieve profitability. However health is the most limiting factor to capturing these advantages (Baysinger 1996). Beyond the financial impact of raising healthy animals, there is no doubt that illness is a most obvious sign of poor welfare. For a long time disease prevention has been a main concern for both farmers and animal scientists, especially veterinarians. Unfortunately in the pig, as in other livestock, despite the indisputable advantage of prevention rather than cure, preventive veterinary medicine has had major difficulties to develop and become the fully recognized discipline which it should be. It is a truism to say that in animal production, as in many other fields, the problem must already be there before we feel really concerned about it. In the pig, this inhibition regarding prevention is all the more questionable since the biological cycles in this species are short, so that different growth stages are frequently present on the same farm. This should logically stimulate prevention through the removal of "at-risk" conditions in the groups which are still healthy because they are younger than the ill group. However, numerous initiatives have been taken in order to develop and promote disease prevention. This chapter will first focus on the different kinds of diseases that can be defined from an epidemiologist's point of view. Subsequently, the main means available for preventing disease will be reviewed.

4.7.1 Disease classification and consequences for prevention

In its common sense, the word disease is related to illness, and to pain, with usually an underlying pathogenic cause. Depending on their aetiology and on epidemiologic considerations, diseases, and especially those encountered in the pig raised in intensive production systems, can be classified into three categories :

4.7.1.1 Notifiable diseases

These have in common the point that they are induced by a well identified pathogenic agent, often a virus. This agent plays by far the most important role in disease occurrence and severity, so that these kinds of diseases can be considered as monofactorial. They can easily be experimentally reproduced in controlled facilities through inoculation without invasive artificial routes or heavy inocula. Their impact on the pig population of an area can be dramatic because of the virulence of the responsible agent and often its ability to spread from farm to farm. Furthermore, other animal species than the domestic pig can become infected with the corresponding pathogenic agents. For all these reasons, such diseases are called notifiable and subject to special official regulations. Amongst others, Foot and Mouth Disease, Swine Fever and Aujeszky's Disease fall into the category. The first two mentioned are included in list A of the International Office of Epizootics (OIE, 1992).

4.7.1.2 Other viral spreading diseases

Their main characteristic is their ability to spread, including through airborne transmission of the virus. However, in this case, the direct threat is less for the whole pig population in an area than it was for the previous group and the economic consequences are also less severe. The severity of the disease impact can be related to the health level of the herds prior to infection. They take a collective form in a herd. The immune status regarding the related infectious agents will greatly determine the course of the disease on farms. Examples are Transmissible Gastro-Enteritis (TGE), Swine Influenza and Porcine Respiratory and Reproductive Syndrome (PRRS).

4.7.1.3 Enzootic diseases

In this case the disease develops within the herds. The cause is not always primarily an infection or an infestation. In case of infectious diseases, transmission from farm to farm is mainly due to trade of carrier pigs. In contrast to the previous two groups of diseases, husbandry and hygienic conditions play the most important role in the impact of the disorders. In other words, the pathogenic agents must find on the farm specific conditions to grow and hence exert a serious pathogenic deleterious effect. That is why most of them are called multifactorial diseases (Kovacs 1978). Enzootic pneumonia, white scour syndrome in the piglet, postweaning diarrhoea, swine dysentery in the fattening pig, parvovirosis, MMA syndrome (Metritis-Mastitis-Agalactia) in the sow and several other health disorders can be included in their category. These health problems are strongly environment-dependent. Some of them are entirely man-made disorders, like the thin-sow-syndrome leading to abortion and fertility disturbances and due to underfeeding and poor hygiene. Inadequate quality of the feed (moulds, natural toxins) that can also induce severe health disturbances (Diemak and Green, 1992; James *et al.* 1992) also enters this category.

The following list contains some of the common enzootic disease conditions which affect pigs in intensive production systems with varying but considerable incidence. The list also illustrates the variety of means of prevention which can be applied, some of which will be described in the following sections.

Disease	Prevalence of pigs with clinical disease at herd level	Duration of Clinical disease	Prevention
Enzootic Pneumonia (mycoplasma related pneumonia)	medium to high	weeks	* Restocking with animals from uninfected source (SPF production) * Eradication by part depopulation and short strategic medication * all in / all out * max 200-300 pigs per unit * segregated early weaning * multi site * reduction in moving / mixing pigs * unidirectional pig flow * optimal climate with high air quality
Pleuropneumonia (Actinobacillosis)	low to medium	days	* Restocking with animals from uninfected source (SPF production) * all in / all out * max 200-300 pigs per unit * segregated early weaning * multi site * reduction in moving / mixing pigs * unidirectional pig flow * optimal climate with high air quality
Atrophic Rhinitis (Toxigenic Pasteur-ella multocida)	low to medium	months	* Restocking with animals from uninfected source (SPF production) * all in / all out * segregated early weaning * multi site * unidirectional pig flow * optimal climate with high air quality
Swine Dysentry	low to medium	weeks	* Restocking with animals from uninfected source (SPF production) * Eradication by part depopulation and short strategic medication * all in / all out * unidirectional pig flow
Gastric Ulceration	low	months	* coarsely ground feed
Postweaning diarrhoea	low to medium	days	* Optimal climate * Restricted feeding

4.7.1.4 Consequences for prevention

Based on this classification, a few conclusions can be drawn with respect to prevention:

1) In every case in which a known causal micro-organism is involved, measures should be taken to prevent contamination, that is to keep those undesirable pathogenic agents outside the herds. In recent years, a great effort has been directed at developing laboratory assays aimed at the detection either of

antibodies or of antigens. These provides very useful tools to policy makers, especially with respect to pig movements.

2) In addition, for monofactorial infectious diseases, vaccination, if available, can be of great interest to prevent a very severe clinical expression in case of further contamination. Furthermore, viral shedding can also be reduced in pigs becoming infected after vaccination compared to non-vaccinated pigs. Results have been obtained concerning this in Aujeszky's disease (Vannier *et al*. 1995). With respect to the use of vaccines, the situation might differ between notifiable and non-notifiable diseases and depends on the type of vaccine. Marker vaccines make it possible to follow concurrently the spread of infection and the level of vaccination in the concerned populations.

3) Obviously in the case of multifactorial disorders the main task is to maintain health in the pig by keeping the microbial load at the lowest acceptable level. Work should primarily be focused on feeding, housing, hygiene and husbandry, although vaccination might help. In the same way, prevention based on systematic massive use of antibiotics is neither relevant nor wise.
4) During the last decades, the wide range in health status of herds and the development of breeding pyramids with a permanent flow of replacement stock suggested the use of a specific terminology. The expression "Specific-Pathogen-Free" (SPF) is normally used to describe pigs derived by caesarean or hysterectomy and reared in an environment keeping them free from pathogenic micro-organisms which can be listed (Muirhead 1988). The terms "Minimal Disease" (MD) and "High Health Herds" (HHH) are also used in some regions. Depending on the people concerned, these words refer to the presence of the pathogens or to disease occurrence. Since pathogenic agents might be present without any obvious clinical signs, it is necessary for practical use to get, in every case, to get a clear definition and a complete check-list of what is behind these words.

4.7.2 The means available for disease prevention

The different ways to achieve disease prevention in animal populations have been documented by epidemiologists (Martin *et al*. 1987; Toma *et al*. 1996). Either involving a micro-organism or a toxin, contamination is often, if not always, the first step on the way to disease. On the other hand, contamination does not systematically turn into disease as it can be clinically perceived. A distinction will thus be made between contamination and disease prevention.

4.7.2.1 Prevention from contamination by exotic pathogenic micro-organisms

Insofar as a pathogen is involved in a disease and reliable laboratory methods are available, it becomes possible to establish the status of a herd or an area (region, country) in this respect. This is the field of descriptive epidemiology and it uses criteria like prevalence and incidence. They give the proportion of infected individuals (pigs, herds) at a certain date and the number of new cases over a period of time respectively. By performing such recordings on regular basis and following adequate rules for sampling, epidemiosurveillance programmes can be set-up. The main final objective of such programmes is, through the knowledge of the situation, to prevent infected animals from moving to non-infected farms. Regarding notifiable diseases, each EU member country must make recordings by its own national veterinary services and, for certain diseases, the outbreaks must also be notified to the EU Commission (directive 82/894).

In case of importations, blood investigations can be undertaken by the national veterinary services to look for notifiable diseases. The pigs, after import, are kept in isolation (six weeks of quarantine with another blood sampling at the end of this period to detect a possible incubation and seroconversion during isolation period).

If an outbreak of a notifiable disease occurs, the national veterinary services take the lead in operations whilst the EU permanent veterinary committee is informed and involved in the discussions. A complete list of actions is implemented in these cases, including destruction out of herds and other severe measures which might come into force to prevent the disease from spreading. After removal of the animals, the facilities are submitted to a cleaning-disinfection protocol (Owen, 1995; Fotheringham, 1995).

At the herd level, since contamination is to be feared, preventive measures have to be taken. Those related to notifiable diseases and mentioned above (purchasing pigs from herds and areas certified free, isolation) are obviously also of value for the other infectious diseases, keeping in mind that the pig itself is the main carrier of pathogenic agents (Kirkegaard 1996). Thus, when populating herds, the solution of purchasing SPF or MD breeding stock is wise. However this option must not be chosen without ensuring that numerous other measures will be taken to keep the high health status. These other protective measures have been reviewed. In densely populated areas, airborne transmission of viral diseases is a real threat (Sellers *et al*. 1977; Christensen *et al*. 1990). Numerous vectors can bring in pathogenic micro-organisms: slurry spreading in the neighbourhood, material and visitors coming from other pig farms, birds and rodents coming in contact with pigs. It must also be mentioned that semen is a potential vector of micro-organisms and especially of viruses (Madec and Vannier, 1989; Philpott, 1993; Swenson *et al*. 1994). Finally when pigs are kept outdoors, additional risks of contamination exist through contacts with wild fauna, the wild boar in particular.

4.7.2.2 On-farm prevention from contamination of subsequent groups of pigs by already resident pathogens

When pathogens (non notifiable) are present in the herd, the farmer's challenge is to find a way to manage the microbial load. Different strategies have been proposed in order to control disease by means of limiting contamination (Baysinger 1996). Traditionally, they rely on the use of antibiotics and vaccines. These tools are still in use, but new technologies have been suggested which, besides a positive effect on health, may have the advantage of limiting antibiotic prescriptions. The idea is to clearly keep the pigs in groups of small to moderate size in separated compartments, to prevent too high a microbial pressure and between group contamination. They can be listed :

a) All in all-out technology in order to break the disease cycle between groups of pigs. Hygienic procedures (thorough cleaning of the facilities, removal of the slurry, disinfection) are necessary additional measures.

b) Temporary pig flow disruption (partial depopulation). This consists of the partial depopulation of a section of production in a unit (with cleaning and disinfecting measures in-between).

c) Segregated Early Weaning (SEW). Most data by now indicate that the sow is a major reservoir of micro-organisms and the piglets get infected progressively during the suckling phase. Early weaning (usually 14 days or less) and keeping the weaned piglets in appropriate facilities have been proposed to obtain cleaner piglets. SEW is a combination of many technologies: all-in/all-out, disruption of pig flow, early weaning. Although the contamination chain can hardly be totally ruptured for all pathogens, even with the use of antibiotics (Amass *et al*. 1996), the system seems efficient provided that adequate technical conditions are met (Dritz *et al*. 1996).

d) Multi-site production. Especially of value in large size operations, it integrates the previously mentioned technologies and, additionally, the sows are housed on one site, the nursery in another, the fattening pigs in a third. Usually the pigs are mixed and sorted on a liveweight basis in order to obtain homogeneous groups in the pens. In some cases the option leads to transport of the pigs over a long distance, and this is not without consequences for welfare (Bradshaw *et al*. 1996).

4.7.2.3 Prevention of disease expression

Clinical disease is often the normal event following contamination of a herd by an exotic pathogen. However, the severity of the disorders can vary widely from herd to herd depending on immune status and on several other factors. After the first wave, a quick recovery can be observed but, in most enzootic disorders, the pathogen still remains more or less active within the herds. As a consequence, in current running operations, the level of disease expression might be different despite the fact that the pathogens that can be detected are found to be the same (Fairbrother *et al*. 1994; Guzylack *et al*. 1997). As an example, the positive effect of all-in/all-out practice on the growing finishing pig was been demonstrated (Scheidt *et al*. 1995). This means that it is not the pathogens *per se* which make the difference, but other on-farm conditions. These are called risk factors since they increase the probability that trouble will occur or become more severe. Analytic epidemiology deals with research in this field. The general principle when risk factors have been detected, should be to build-up and implement relevant preventive programmes on the farms based on scientific knowledge, with the objective of removing these risk factors and thus creating better conditions for the pigs. Rapid development of computer and communication technology greatly enhances the possibilities for data collection, calculation and information transfer.

Herd health programmes can include actions directed at the contamination chain through the provision of SPF or MD pigs starting with the top of breeding pyramids (Petersen 1995). However, most of the health monitoring schemes aim at an evaluation of the health/disease level of farms (Lingaas and Ronnigen 1990, Puonti and Saloniemi 1990, Pointon and Banhazi 1995, Carlton 1995). Slaughterhouses are the main source of data about health through lesion recording (Christensen and Cullinane 1990, Elbers 1991, Almond and Richards 1992). By combining abattoir data with information gathered on the farms (clinical signs, production and welfare indices) and at the laboratory, comprehensive data bases can be obtained which, in turn, have to be used in the monitoring process. Such integrated systems have been proposed (Willeberg *et al*. 1984; Petersen *et al*. 1989; Ekesbo, 1992; Blocks *et al*. 1994). An important issue is the feed back of information to the farmers and to their advisers for decision making.

Depending on the scheme and on the recordings, the type of results that come out is broadly different. The role of general variables (season, herd size) can be easily tested, but for practical intervention there is a need to go deeper into the recordings related to the description of on-farm management procedures. Consequently, besides or linked to health monitoring schemes, surveys can be designed which aim at finding out specific risk factors through the comparison of herds or batches of pigs concerned with a given health disorder to healthy non concerned herds. Such surveys, either prospective or retrospective, provide the scientific basis for disease prevention. Numerous studies of this type have been published about pig enzootic diseases where management is strongly involved (Madec and Josse 1983, Mousing *et al*. 1989, Hofer *et al*. 1996, Gardner and Hird 1994).

Within Epidemiology, the word "ecopathology" is used to name studies about the relationships between disease and management, the latter including stockmanship but also the microbiological aspects (Fourichon, 1991; Madec, 1995). Experiments in controlled facilities are useful complementary works to these epidemiological studies (Kelley, 1982; Tielen 1986; Schepens *et al*. 1991). The accuracy of risk factors must be verified. A risk factor may have different effects on disease incidence depending on the presence of other conditions (Boyko and Alderman, 1990). For this reason it is wise to study risk profiles combining different variables. Furthermore, the risk factors related to a given syndrome might be different from place to place and they can change with time in a given place, showing the need to periodically update the studies. Updated, reliable information issuing from epidemiological surveys can be included in expert systems specifically designed to help herd health maintenance (Vos *et al*. 1990). The latter can be devoted both to farmers and to advisers.

The conclusions of most studies aimed at assessing the risk factors of enzootic diseases have demonstrated, though indirectly, the role of stockmanship. Husbandry deviations are frequently the source of risk factors (Kovacs, 1978). The majority of health disturbances in modern farm units have to be prevented through collective, herd management measures, that is through more appropriate zootechnics. This raises the problem of not only the farmer's education but also of his advisers. Pig farmers are still more willing to consult veterinarians about individual sick animals than about broader issues related to management or production (Friendship, 1990). On the other hand, scientists and especially veterinarians tend still too much to base their action on the belief in an exclusive causative relationship between disease and pathogenic micro-organisms.

4.7.3 Disease treatment

The control and treatment of disease is initially dependent on its accurate and early diagnosis. The application of new techniques allows a new sensitivity in diagnosis. Paul (1996) overviewed the latest advances in diagnostic technologies and the utilisation of diagnostic results to prevent and control infectious diseases. Westergaard (1996) discussed health strategies to control pig infectious diseases in Europe.

The development of new medicines capable of eliminating certain microbial pathogens, and the technology for administering them in the proper and permitted amounts, have contributed to the main effective practical method of disease treatment (Aitken *et al.* 1996; Stocker *et al.* 1996). On many occasions, the effective treatment of a disease outbreak might require a selected combination of chemotherapeutic, management and environmental procedures. No one combination is equally applicable to all affected herds. Herd health status will also dictate the treatment measures and procedures. Therapeutics can be administered to the sick animals by parenteral routes or dosed orally. Severely affected pigs should be treated individually when water or feed medication is used.

It is important that every pig farm has an isolated area for sick animals where small groups or individuals can be accommodated. Proper care to reduce pain and suffering of any sick animal must be taken.

4.7.4 Conclusion

45. Infectious diseases are important welfare problems. Effective health-care therefore requires that pigs are kept in an appropriate environment. Strong measures, for example good hygiene and careful routines with purchased pigs, can help in avoiding infection of herds with pathogenic micro-organisms.

46. Many diseases are multi-factorial and, even when there is an infectious agent, their development depends on the husbandry conditions of the pigs. Effective health care therefore requires that pigs are kept in environments which do not cause stress and immune system inadequacy.

47. Recommendation: Herd health is best if animals from different farms are not mixed together. However, where such mixing is necessary, appropriate isolation and other treatment to minimise cross infection is necessary. In order to minimise disease in all pigs, they should be kept in environments which do not cause stress and reduced immunocompetence.

4.8. Genetic Selection and Pig Welfare

4.8.1 Introduction

One of the basic approaches to efficient pig production is changing the genotype. In the last 50 years most of the genetic improvement in production came, and it still comes, from intensive selection of better genotypes in pure bred lines (Kanis 1989). Commercial production usually involves cross breeding from purebred lines.

Genetic improvement of production by conventional selection techniques is a slow process. Techniques for altering the balance between lean and adipose tissue growth involve genetic selection and employment of a variety of management strategies, including the use of intact males, controlled feeding and lower slaughter weights.

In addition to classical selection programmes, genetic engineering and administration of biotechnological products can improve important performance traits like leanness and growth rate. Genetic manipulation of animals has the capacity to introduce major changes in the genetic composition of animals within a very short interval. The use of a single product like recombinant porcine somatotrophin, makes it possible to obtain increases in growth rate and feed efficiency amounting to about 20% (Cambell *et al.* 1988, Evok *et al.* 1988). These achievements would normally have required 10-20 years of intense genetic selection (Boyd and Wray-Cahen 1989).

The criterion for selecting animals for use in breeding has been an increase in economic performance and this has often not coincided with improved animal welfare. Hence the term "genetic improvement" is misleading since, in some cases, the changes are not improvements for the animal but may make the life of the animal more difficult. The consequences of genetic change by classical selection and by genetic engineering on pig welfare are briefly described in this chapter.

4.8.2 Genetic Change by Conventional Breeding

Until 1980, the main classical selection objectives were for fat reduction and thus improvement of feed conversion efficiency. For quite some time there were no obvious unfavourable side effects. But, later on indications arose that selection for leanness was accompanied by reduced appetite (Smith and Fowler 1978, Henry 1983, Webb and Curran 1986, Kanis 1988), meat and fat quality problems (Kempster *et al.* 1986, Wood *et al.* 1986, Wood *et al.* 1992) and unfavourable effects on reproductive performance (Gaughan *et al.* 1995).

Genetic selection has increased both the rate of lean growth during the growth phase and the total lean mass of a mature pig. These changes are likely to have 1) reduced the voluntary feed intake of pigs at any given live weight and 2) increased the mature body size of pigs (Taylor and Murray 1987).

The mechanisms that control appetite (voluntary feed intake) are described in a review by Revell and Williams (1994). The reduction of appetite in response to a selection index for growth performance and backfat thickness under ad libitum feeding, has been most clearly demonstrated by Smith *et al.* (1991). Over an 11 year period of selection, they have shown a reduced appetite for both boars and gilts over the live weight range of 30-90 kg. For selected boars, voluntary feed intake remained about 10% below control while for selected gilts it was similar to control animals at 30 kg live weight but began to diverge, such that by 90 kg live weight gilts consumed less than control boars.

Selection for low daily feed intake, either directly or indirectly through selection for high lean feed conversion efficiency, may limit the animal's ability to express its genetic potential for growth (Ellis *et al.* 1983, Kanis 1990, Whittemore 1993).

Until recently, selection for reproductive traits has been subject to less attention in commercial breeding programmes (Haley *et al.* 1988). Several studies have measured the responses of reproductive traits with selection for lean growth but, in general, the responses have been low (Freedeen and Mikami 1986c, Cleveland *et al.* 1988, Kuhlers and Jungst 1992). Young *et al.* (1990) demonstrated the lack of influence backfat has on puberty attainment. Beltranera *et al.* (1993) suggest that backfat depth will influence puberty attainment when it falls below 6 mm. Gaughan *et al.* (1995) pointed out that selection techniques based on growth rate and leanness have resulted in leaner pigs and have reduced the age at puberty, but have not increased reproductive efficiency. However Cameron (1994) noted that cumulative selection differential of animals selected for low voluntary feed intake was substantially lower than with selection for high daily feed intake, due to reduced reproductive performance. Kerr and Cameron (1995, 1996), in two experiments, reported that selection of pigs for low daily feed intake or high lean food conversion efficiency significantly reduced reproductive performance after five generations of divergent selection. They concluded that selection strategies which result in low daily feed intake may have a negative effect on reproductive performance.

A great deal of research has been focused on the problem of osteochondrosis (OC) which is considered a major cause of the clinical syndrome of leg weakness of pigs in Europe and North America (e.g. Grondalen 1974, Reiland 1978, Hill *et al.* 1984, Nakano and Aherne 1988, Stern *et al.* 1995). Leg weakness and OC in pigs have been reviewed by Nakano and Aherne (1987). The causes of OC, as well as the economic relevance and countermeasures, have been reviewed by Hill (1990a, 1990b) respectively. OC is a non-infectious disease of the epiphyseal and subchondral tissue and defines a group of syndromes that cause limb deformities and degenerative joint disease (Hill 1992). The pathogenesis of the disease is still undetermined (Nakano and Aherne 1994) and results of experimental investigations are often contradictory.

Osteochondrosis appears to be one result of long-term selection for desirable carcass qualities combined with intensive management systems (Palmer 1993). There is a positive correlation between these qualities and lesions of OC which is associated with high levels of growth hormones (He *et al.* 1994). Not all pigs with lesions develop the disease, although in some groups of breeding stock disease prevalence approaches 100%. The reasons for such high morbidity are not apparent, but in general any factor that increases physical stress on the skeleton or which reduces the ability of the skeleton to resist that stress could be significant. In this regard it is not uncommon for ischiatic epiphysiolysis to occur in young sows after breeding, and there is little doubt that rapid weight gain prediposes to the development of the disease (Palmer 1993).

In pigs with a strong genetic contribution from the European wild boar, a slow growth rate and absence of lesions of OC were considered to be related Reinald (1978). However Uhlhorn *et al.* (1995) found lesions of OC in a slower growing crossbred pig population of wild boar and Swedish Yorkshire ancestry. Histological lesions have been demonstrated in piglets at 1 day of age (Bullough and Heard 1967, Visco *et al.* 1991) and may therefore be congenital as well as hereditary. The hereditary nature of the OC requires close examination because selection characteristics such as overall leanness and larger muscles are those that seem to be correlated with higher frequency of osteochondrotic lesions which also trend to be more severe. There is an association between leg weakness and the severity of lesions. Stern *et al.* (1995), although they recorded inconsistent genetic correlations between growth rate and OC scores, concluded that, in the long term if high selection pressure on lean content and performance is maintained, leg weakness is likely to get worse. On the other hand, Nakano *et al.* (1987) concluded, in their review article, that no simple association between growth rate and the incidence or severity of OC has been consistently demonstrated. Indications of unfavourable correlations between growth rate and OC have been found by Lundeheim (1987) and Carlson *et al.* (1988).

With the selection of increased growth rate pigs are now heavier at any particular age. As a consequence there has been a steady increase of the mature body weight (Aherne *et al.* 1991, Whittemore 1994). Gilts today tend to be mated at a given weight or age and sows begin their reproductive life at a lower proportion of mature body weight, and hence are physiologically younger than the gilts of the 1970's at their first mating. The influence of age and body weight on the onset of puberty in gilts and subsequent productivity has been reviewed by Paterson (1989). In animals still growing fast during pregnancy, there may be a diversion of nutrients away from the developing fetus towards maternal tissue. As a result, birth weights may be reduced. The extent of the problem in the modern-genotype gilt is uncertain. Heavy pigs are more susceptible to osteochondrosis, which is likely to be painful and which certainly impairs movement. Another consequence of heavier pigs with less fat, and excessive leanness is an increase in the energy requirement for maintenance (Campbell and Taverner 1988, McCracken 1993).

The most noticeable problem of pigs kept for meat production is that, during handling and transporting to slaughter, a few die, rather more are obviously adversely affected and many have some degree of pale, soft, exudative meat (Broom 1994). Grandin (1989) states that indiscriminate over-selection for single traits in pigs has caused many problems such as an extremely nervous temperament in lean fast growing pigs. These animals are very difficult to handle humanly in a high speed slaughter plant. Dämmrich (1987) showed that selection for muscle block size had had consequences which explain the mortality or other adverse effects which occur when pigs exercise vigorously. The larger muscle, Type II, fibres in the Landrace breed exceed the limit above which capillary-to-fibre distance is too great for adequate metabolic removal. In these large fibres, lactic acid will accumulate. Finally, heart strain is more likely in modern breeds because the heart is smaller in relation to body weight: 0.21% of the body weight in the Landrace but 0.38% in a wild boar (Dämmrich 1987).

The problem of Porcine Stress Syndrome (PSS) has attracted increasing attention in the last 20 years (Webb 1981, Topel and Christian 1986, Whittemore 1993). Pigs affected by PSS have a high liability to develop pale, soft, exudative meat (PSE) and to die in a shock-like state. A high emphasis on extreme muscle deposition and ham shape in selection, caused a well established relation between PSS and PSE. Ollivier *et al.* (1978) showed a strong relationship between muscular development and stress susceptibility. The porcine stress syndrome is closely related to the genetic constitution of the pig. It is associated with the presence in the genotype of the “halothane gene”, (thus named because the animals react to the anaesthetic halothane), an autosomal recessive gene of variable penetrance, with both beneficial and harmful effects on production traits. Pigs with the homozygous nn (halothane positive reaction) for the halothane gene show an increase in carcass lean but much greater susceptibility to sudden death and a higher incidence of PSE compared with the normal homozygous NN (halothane negative reaction). Halothane positive reactors are found at various levels in pig populations, with the more muscular breeds and strains being more susceptible to PSS. Halothane positive sows have smaller litters at birth and weaning (Garden *et al.* 1985, Taylor 1995) and significant reductions in average litter weight at birth (Simpson *et al.* 1986).

Elimination or reduction in the incidence of this hereditary problem depends on the identification of the PSS animals and carriers of the halothane gene, and their subsequent elimination from the breeding herd. Reliable tests have been developed in recent years (Brem and Brenig 1992, Rempel *et al.* 1993) that can be used for the elimination of the halothane gene from any herd because they accurately identify not only the homozygous nn but also the heterozygous Nn stress susceptible animals.

A trend in pig breeding which has led to rapid change within the last few years is selection for prolificacy (Legault 1996). Both crossing with breeds, such as the Meishan, from east Asian countries and selecting for the most prolific of existing breeds, have increased the number of piglets born (Legault and Caritez 1983, Bidanel *et al*. 1991, Ashworth *et al*. 1992). Increases in the numbers of piglets born may well lead to a higher proportion of low birthweight piglets and hence to higher mortality and a greater incidence of poor welfare in piglets. Piglet weakness and mortality is one of the serious welfare problem areas in the pig industry so it should not increase. Greater prolificacy should not be permitted if the proportion of piglets whose welfare is poor increases.

4.8.3 Genetic Change by Genetic Engineering

Genetic manipulation, or genetic engineering, involves the alteration of the genome of the animal in such a way as to permanently alter the capacity for growth. The isolation and sequencing of the genes associated with the growth function in the pig, in combination with advances in recombinant DNA technology, has presented the opportunity of directly manipulating the genetic capacity for growth. The production of transgenic pigs is difficult and costly, but a successful outcome offers the opportunity to make large genetic gains in a short time (Vries and Mewsson 1991, McCauley *et al.* 1995). The possible implications for genetic improvement of administration of pST and use of transgenic pigs were considered by Kanis (1989).

The first report of transgenesis in the pig involved insertion of the structural gene for hST (Hamer *et al.* 1985b). In some of the transgenic pigs produced by Pursel and co-workers (Pursel *et al.* 1990), overall growth response was favourable. They grew more rapidly and efficiently than controls, indicating that the extra ST was acting in a similar way to the endogenous hormone with respect to tissue growth. The amount of ST in the serum varied widely but those with prolonged elevations exhibited a number of adverse effects. These induced lameness (skeletal and joint abnormalities), ulcers, cardiomegaly, lethargy, renal disease, susceptibility to stress and infertility. These undesirable side effects ranged from mild to severe.

Extra copies of the genes of two other growth related hormones, growth hormone releasing factor (GHRF) and insulin like growth factor I (IGF-I) have been inserted into pigs (Pursel *et al.* 1989a; 1989b). Most of these transgenic pigs did not survive long enough for performance testing.

Broom (1995) emphasizes that, 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.

No comprehensive study, using an adequate variety of measures, of the welfare of transgenic pigs or pigs treated with substances produced by recombinant DNA technology has yet been reported in the scientific literature. Only some aspects of pig welfare assessment have been covered by Van der Wal, Niewhot and Politiek (1989) and by Fiems, Cottyn and Demeyer (1991). More recently, some more aspects and considerations have been reported (Boer de *et al.* 1995, Poole 1995). Methods of assessing the welfare of modified or treated animals are reviewed by Broom (1993, 1997).

4.8.4 Conclusions

48. Selection for large muscle blocks and fast growth has led to leg problems, cardiovascular inadequacy during periods of high metabolism and increased risk of mortality and poor welfare during handling and transport. Although some of these problems have been addressed, there are important welfare problems which are attributable to the selection procedures.

49. Recommendation: No selection should occur without reference to the effects of that selection on welfare of piglets, growing and finishing pigs and breeding animals. The continuation of new genetic lines in which the welfare of the animals is, on average, worse than that of existing lines should not be permitted.

50. Body composition at selection has an important role in lifetime reproductive efficiency. Genetic selection of fast growing lean pigs has led to impressive gains in the lean tissue deposition. Little attention has been given to feed intake and the modern genotypes may in fact be too thin.

51. Recommendation: Nutritional input and strategies must be targeted towards meeting the specific requirements of the animal and ensuring good welfare.

52. Selection programmes where halothane positive genetic lines for more lean meat and better ham shape are maintained, increase the prevalence of stress susceptible pigs. The pathogenesis of osteochondrosis is not well understood but high growth rates appear to be one important risk factor.

53. Recommendation: Even where some production lines will be lost, a strategy aimed at eliminating the halothane gene from breeds or lines is necessary. Genetic selection programmes should include selection against osteochondrosis and other health disorders.

54. Selection for prolificacy is leading to increased numbers of piglets being born alive but of low birth weight and hence to an increased proportion of piglets dying before weaning age is reached. Piglet weakness and consequent mortality is a serious welfare problem.

55. Recommendation: Selection for prolificacy should be accompanied by selection for increased piglet rearing capacity in sows such that there is no increase in the proportion of piglets born alive which suffer or die before weaning.

56. Surprisingly, work on the welfare of transgenic pigs or pigs treated with substances produced by recombinant DNA technology is not abundant in the scientific literature.

57. Recommendation: Evaluation of transgenic animals should include overall performance tests involving scientific studies of welfare as well as production and reproduction traits. The evaluation should be done under practical field conditions for at least two generations.

4.9. Growth promoters

Consistent progress has been made over the last decades in our scientific knowledge of growth physiology. The regulation of growth, including the cellular aspects, has been deeply investigated (Allen *et al.* 1979, Breier and Gluckmann 1991, Pearson and Dutson 1991, Dunshea 1993, Caperna *et al.* 1994). Due to a strong economic impact, an emphasis has been given to meat production. As a consequence, new technologies have been developed in order to achieve a better growth rate and, especially, improved lean meat production and feed conversion ratio through an activation and/or a modification of metabolism (Heap *et al.* 1989, Van Der Wal *et al.* 1991). In Europe, the use of growth promoters for pig production is still debated, as it is in other species. On the one hand, there is evidence of a better nutrient accretion in the body and consequently the potential for lower production cost and less waste into slurry. On the other hand, growth promoters might not be entirely safe for the animals and for the meat consumer. Furthermore, from the public standpoint, the image of livestock production might become tarnished through the use of growth promoters on a routine basis. Finally, a non-uniform regulation in different countries might generate unfair conditions in international trade. The different aspects of growth promotion in meat production have been recently reviewed in a conference held in Brussels under the auspices of the EU in December 1995 (EU report 1995). Only those aspects which may be useful to the pig welfare directive revision are considered here.

There is a variety of substances capable of enhancing growth in the pig and further innovations are probably under way.

4.9.1 Anabolic steroids

Growth promoting steroid hormones can be divided into 4 categories (EU 1995):

- natural steroids: progesterone and testosterone
- xenobiotics: trenbolone acetate and zeranol
- synthetic steroids: ethinyloestradiol, methyltestosterone, chlormadinone acetate...
- diethylstilboestrol and related substances: hexoestrol, dienoestrol..

The myotropic actions of anabolic steroids result from their ability to increase retention of dietary nitrogen through protein synthesis. Steroid hormones may act in different ways: via specific cell receptors, by enhancing endogenous somatotrope hormones and finally by modulation of endocrine systems such as the gonadal, thyroid and adrenal axes (Renaville *et al.* 1995). In the eighties, these compounds were tested alone or in combination. Oestrogen implantation slowly increases carcass fat and reduces boar odour (Galbraith and Topps 1981). Combinations of oestradiol 17-β + progesterone or testosterone or Trenbolone slightly increase daily gain and feed conversion ratio (De Wilde and Lauwers 1984). Attempts made to use trenbolone (allyl-Trenbolone) in the feed of lactating sows to stimulate reproductive performance showed inconsistent benefits (Costa and Varley 1994). Generally speaking it can be said that the pig has remained much less concerned by anabolic steroid administration than other species and this is probably due to the poorer responses obtained. Very limited data are available on the possible effects of anabolic agents on animal health and welfare. Recent work in steers has shown changes in the mass and health of viscera after implantation (Hutchenson and Johnson 1994, Preston *et al.* 1995). Implantation at an early age with different growth promoting steroid hormones and/or glucocorticoids in male bovines had a negative effect on behaviour, testicular growth and spermatogenesis (Baker and Gonyou 1986, Godfrey *et al.* 1992, Renaville *et al.* 1994). Detrimental consequences have also been demonstrated in heifers (Moran *et al.* 1990, King *et al.* 1994).

In this field, data about the pig are scarce. The only studies concern the treatment with corticoids. Pigs treated with dexamethasone had larger liver and kidneys but smaller spleen than the controls (Flaming *et al.* 1994). They also found a relative neutrophilia and lymphopenia.

The EU report (Renaville *et al.* 1995) concluded that, provided that natural Steroids and xenobiotics are used at the recommended doses, and in the correct manner, and if the delay before slaughtering is respected, there is neither danger for the health of the animals nor for the consumer. On the other hand, synthetic Steroids and Corticoids must be prohibited. Moreover, anabolic agents are not recommended for replacement animals because of possible detrimental effects on fertility.

4.9.2 Growth hormone and related peptides

As early as the 1920s, it was strongly suspected that the anterior pituitary gland was involved in physiological processes and in growth in particular (Evans and Simpson 1931). In the mid 1940s growth hormone (or somatotropin) could be isolated. Pig somatotropin consists of a single polypeptide chain made of 191 amino acids (molecular weight = 22 000). The effects of growth hormone and related peptides have been reviewed by Bonneau (1991a, 1992b), by Louveau *et al.* (1995), and by Sejrsen *et al.* in the proceedings of the EU Conference in 1995. Three groups of hormones are related to the somatotropic axis:

The hypothalamic factors: GRF (growth hormone releasing factor) and somatostatin (somatotropin releasing inhibiting factor)
Somatotropin (ST or GH)
Insulin-like growth factors (IGFs)

Growth hormones are extensively digested after oral ingestion. They have to be administered by injection or by sustained release vehicles (Buonomo *et al.* 1995)

4.9.3 Growth hormone releasing factor (GRF)

GRF is a peptide (44 amino acids) stimulating GH release. There is a close homology between GRF molecules found in human and in farm animal species (bovine, ovine and porcine). Treatment of pigs tends to modify carcass composition (less fat, more lean) and in some cases to increase growth (Etherton *et al.* 1986, Dubreuil *et al.* 1990, Johnson *et al.* 1990). Depending on the trials, the daily doses varied from 5 to 40 µg/kg liveweight and the compound was injected from 1 to 3 times per day throughout the period (Bonneau *et al.* 1991b).

4.9.4 Growth hormone (GH, PST or Porcine somatotropin)

The anterior pituitary is the site of growth hormone production. Production and release of PST are regulated by several compounds, hormones and peptides including GRF and somatostatin (Rawlings and Mason 1989). The recent development of recombinant-DNA techniques has resulted in more available amounts of PST and a large number of trials could be performed. In the muscle tissue, PST increases protein accretion, protein synthesis and glucose uptake, whereas in adipose tissue it decreases glucose uptake and lipid synthesis. A number of studies have been carried out on the effects of exogenous PST administered to the pig. The usefullness of PST treatment on reproductive function in the female has been assessed (Terlouw *et al.* 1989, Beltranena *et al.* 1994) but most work has been devoted to the growing pig. There is a wide range of response in terms of growth rate, amongst which some are negligible, but the most frequent gains go from 5 to around 20% (Kanis *et al.* 1990, Seve *et al.* 1993). A simultaneous decrease is observed in feed intake in *ad-libitum* fed pigs resulting in a considerable, though variable, improvement in feed conversion ratio (Noblet *et al.* 1992). This is mainly due to a major decrease in the subcutaneous fat and in the total carcass fat (up to 40%). On the other hand, the amount of muscle is increased typically between 5 and 20% (Campbell *et al.* 1990, McPhee *et al.* 1991). Part of the discrepancies found in literature may be due to the feeding levels and to the diet composition. Because of an increase in protein accretion, dietary levels of essential amino acids, and especially lysine, have to be elevated for a full effect of PST.

The genotype, the potential for lean tissue growth and the muscle fibre size are also suggested to be involved. Treatment with PST does not affect the number of muscle fibres but some differences could be detected in fibre type frequency (Solomon *et al.* 1990, Lefaucheur *et al.* 1992).

The question of the usefulness of increasing growth hormone concentrations in pregnant and lactating sows has been raised. A review was written by Farmer (1995). Exogenous PST or GRF administered to sows during the last part of pregnancy was not considered promising in order to improve piglet survival after birth, whereas the benefit of these compounds in early gestation aiming at embryo and foetus development was not really known. The involvement of PST in the control of milk production is not as clear in swine as it is in cattle. It was recently found that daily injection of PST does not increase milk production in lactating first-litter sows, despite the fact that metabolism was modified, with a greater decrease in backfat during lactation (Toner *et al.* 1996). Voluntary feed intake was reduced and management procedures, especially feed composition, were found to interact with the response. Since the production of PST is controlled by GRF and also by a GH inhibiting factor, immunization against the latter was also investigated. However, at the time of reviewing, the operation was considered unlikely to improve survival or growth of newborn piglets (Farmer. 1995). Only a few studies have been specifically designed to assess PST treatment impact on health and welfare. However, papers report a negative effect on leg problems (Jorgensen and Sorensen 1994). Osteochondrosis and cartilage lesions were particularly increased (He *et al.* 1994a, 1994b) and low breaking strength of bones was also found (Bidanel *et al.* 1991). Besides locomotor disorders, stomach ulcers may be a second health problem enhanced by PST treatment (Smith and Kasson 1990, Lefaucheur *et al.* 1992). Smith *et al.* (1991) observed detrimental consequences of daily PST on sow health. The periparturient phase seemed to be critical; mortality was reported, mainly due to gastric ulcers (Cromwell *et al.* 1992, Kveragas *et al.* 1996). Furthermore, possible adverse reactions on thermoregulation are suspected because of the reduced subcutaneous fat. Finally, when repeated injections to the animals are needed it is a real constraint.

4.9.5 Insulin-like Growth factors

IGF I and II are peptide hormones involved in metabolic regulation of growth (Lamberson *et al.* 1996). Circulating IGF-I. (a 70 amino acid - peptide) originates mainly from the liver but this source may not be exclusive. The majority of the anabolic effects of growth hormone were thought to be mediated by this growth factor (Sejersen *et al.* 1995) and a recent study shows that IGF-I expression is growth hormone responsive in liver, adipose tissue and certain skeletal muscles (Lamberson *et al.* 1996). A tissue-specific control of expression of the related genes and a tissue-specific promoter usage was demonstrated (Brameld *et al.* 1996). Up to now, recombinant IGF-I is not available in large quantities and this may explain the very limited number of trials carried out on large animals. At the present time no data are available for pigs.

4.9.6 b adrenergic - agonists (b - agonists)

These synthetic compounds have been categorized as β-adrenergic agonists because they share structural and pharmacological properties with the endogenous catecholamines, norepinephrine and epinephrine (Beermann 1995). Different classes of receptors have been made, based on the potential of adrenergic molecules to react in different tissues. Two major types (α and β) were found but the latest investigations showed a more complex situation (Mills and Mersmann 1995). The most extensively studied compounds are clenbuterol, cimaterol, ractopamine, L644 -969, terbutaline and salbutamol. Some of these compounds were initially used as therapeutic agents in human or veterinary medicine (Sasse 1987).

They are orally active and administered in the feed. Information about the mechanism of action of β-agonists can be found in literature (Eiseman 1995, Witkamp 1995). In the pig, ractopamine has been most investigated and it has been commercially developed. Ractopamine administration to growing-finishing pigs resulted in increased carcass lean and a reduction in both fat and bone (Watkins *et al.* 1990, He *et al.* 1993). More recent results are in agreement and increased boneless-cut weights were obtained (Crome *et al.* 1996). Organ weights were either unchanged or slightly decreased with ractopamine (Aalhus *et al.* 1990). It has to be mentioned that a withdrawal period can negate the changes in growth and carcass composition. Compensatory growth of adipose tissue has been seen in pigs after cimaterol treatment cessation (Walker *et al.* 1989). A negative relationship was, however, found between ractopamine dose and motor activity in fattening pigs, but no aggressive or stereotypic behaviours were observed (Schaefer *et al.* 1992). In an open field test, pigs treated with salbutamol tended to behave more passively than the controls (Jensen *et al.* 1994). Plasma ACTH was increased in the treated pigs but not cortisol. Doses for repartitioning effect are 5 - 10 times higher than the recommended therapeutic doses. The conclusion of the EU Conference (EU 1995) was: "*the use of highly active b_2 - agonists as growth promoters is not appropriate because of the potential hazard for humans and animal health".*

4.9.7 Appetite stimulating substances

In some genetic lines of pigs, the full growth potential cannot be totally achieved through *ad libitum* feeding. Superalimentation (forced feeding above *ad lib*) was found to give a response (Pekas 1985). Hence studies are underway aiming at increasing appetite. The role of cholecystokinin (CCK) in appetite regulation has been explored (Walsh 1981).

Exogenous CCK injection suppressed feed intake in rats (Gibbs *et al.* 1973). Attempts were also undertaken in pigs (Anika *et al.* 1981). Since then, studies have been directed at trying to neutralize CCK by immunization in order to increase voluntary feed intake. Cholecystokinin octapeptide immunization stimulated growth in growing pigs by about 7 - 10% (Pekas *et al.* 1993). The way is open for research and development of new technologies in this field. At the present time the consequences for welfare are unknown. These substances are not allowed in the EU at the present time.

4.9.8 Antimicrobial feed additives

Subtherapeutic doses of antimicrobials are approved for use in livestock production to increase growth rate and gain-to-feed ratio (EU Report 1995). Antibiotics are produced by microorganisms and chemobiotics or chemotherapeutics are chemically synthetized. Antibiotics and chemobiotics are drugs and are therefore regulated (Smith 1993, Corpet 1995). The positive effect of subtherapeutic use of antibiotics "at large" for pigs has been clearly shown in a review written by Hays (1991). On average, the rate of gain was improved by about 16%, 10% and 4% for the starting, growing and finishing phases respectively. These data showed a stronger response in young animals. It is presumed that the benefits are achieved through growth inhibition of certain bacteria, like those living in the gut and having an adverse effect. The more developed immune system of older animals may be more efficient to overcome the natural microbial challenges encountered in the herds. Another observation is that the lowest response in terms of growth rate and feed efficiency occurs when the environmental conditions, including nutrition, are adequate. The consequences of antimicrobial feed additives on carcass composition are not generally substantial. However, an improvement of 8 - 9% in nitrogen utilization (N retention: N intake) was obtained in finishing pigs fed on a diet containing either avilamycin or tylosin (Roth and Kirchgessner 1993). It must be kept in mind that the use of antibiotics leads to emergence of resistance in the endogenous bacterial flora (Neu, 1983). Through the years, a significant increase in antibiotic resistance to *E. coli* isolated from rectal swabs of piglets was found (Aalbek *et al.* 1991). Furthermore, a higher prevalence of antibiotic resistance to amoxicillin, Neomycin, oxytetracycline and trimethoprim was found in *E. coli* isolated from pig farmers than from other people (Nijsten *et al.* 1994).

4.9.9 Conclusions

58. Growth promoters can be divided into different families of compounds and they are submitted to specific regulations or recommendations. For most growth promoters, there is a lack of documentation about the welfare consequences of their use.

59. The widespread use of antibiotics and chemobiotics for the purpose of growth promotion and for preventive medication leads to risks for development of resistant strains of bacteria. The development of such strains is a potential welfare problem for all animals including man.

60. Recommendation: Growth promoters which cause negative effects on welfare, including health, should not be used.

61. Recommendation: Routine preventive medication with antibiotics and chemobiotics should not be carried out.

CHAPTER 5 PRODUCTION SYSTEM COMPARISONS

5.1. Boars and service

There appears to be no specific research on the housing requirements of mature boars, although it would be reasonable to extrapolate information on such parameters as space, flooring, temperature, lighting and social stimulation from studies of pigs at other stages. Under natural conditions, mature boars are solitary for long periods of time and join sow groups when the females come into oestrus. It is therefore reasonable to suggest that individual housing is not unacceptable, provided that neither long term sensory or social deprivation are involved. The minimum space requirement, based on a liveweight of up to 300 kg and snout to tail length of up to 2 m, would be a shortest pen side of 2.6 m to allow the boar to comfortably turn around (Petchey and Hunt, 1990). The space required to allow adequate opportunity for exercise, and the consequences of inadequate space for welfare, have not been defined. The present legislation relating to Directive 91/630 specifies a minimum space allowance of 6 m^2 per animal, which would preclude housing of boars in stalls. This has been a common practice in many EU countries, especially where boars are kept for semen collection for use in artificial insemination.

It is normal commercial practice to keep mature boars individually. It has been demonstrated that boars which are reared from weaning without physical or visual contact with other pigs show reduced courting and copulatory behaviour when compared with those reared in all male or mixed sex groups (Hemsworth *et al*. 1977). Subsequent study showed that lack of physical, as opposed to visual, contact could account for 70% of this impairment in behavioural development (Hemsworth *et al*. 1978).

Mature boars will fight if unfamiliar animals are mixed and severe injury can result. Mixing should only be carried out when essential, should never take place in a confined space and should be closely supervised. Appropriate measures reported in practice to ameliorate adverse welfare consequences of aggression include prior trimming of tusks, use of a recommended sedative, a large area with non-slip flooring and no sharp projections, and the presence of oestrus sows to provide distraction.

Housing of individual post-pubertal boars adjacent to sexually receptive females resulted in enhanced courtship and copulatory behaviour in comparison with animals housed in visual isolation or adjacent to other boars (Hemsworth *et al*. 1977). Boars previously identified as being of high sexual motivation showed the greatest detrimental effects of isolation. A subsequent experiment showed that housing adjacent to females which were not sexually receptive was also effective in maintaining male sexual behaviour (Hemsworth *et al*. 1981). The adverse effects of isolation may be permanent if imposed on young post-pubertal boars (<1 year of age), but appear to be reversible in older animals (Hemsworth *et al*. 1983).

Housing of mature boars in a group reduced courtship behaviour but not copulatory performance in comparison with boars which were group reared but housed individually once mature (Hemsworth *et al*. 1978). Group housed boars were reported to be in better physical condition because of improved space for exercise, although some homosexual behaviour was seen and one individual within the group was the major recipient. Other studies (Cordoba-Dominguez *et al*. 1991) have reported that the incidence of sodomy behaviour and aggression within established groups of mature boars is very low.

5.1.1 Housing of the female

Since physiological changes associated with stress have been shown to adversely affect the reproductive endocrinology of the sow (Liptrap, 1970; Hennessy and Williamson, 1983), any housing or management procedures which give rise to reduced expression of oestrus or reproductive efficiency may indicate a degree of stress to the sow. However, there are many other reasons for poor reproductive performance, and poor welfare cannot be deduced solely from impaired performance.

Isolation of weaned sows from boars can delay the onset of oestrus (Walton, 1986). Group housing of sows, as opposed to individual housing in stalls, and daily physical contact with a boar both reduce the weaning to oestrus interval in an additive way (Hemsworth *et al*. 1982). A similar effect of boar presence in the absence of physical contact was not apparent. Young boars (6-7 months) have a lower stimulus value than older animals for the induction of female sexual behaviour and receptivity, which can be enhanced by additional auditory and olfactory stimuli (Hughes *et al*. 1985). Gilts tested for oestrus by a stockperson show a stronger behavioural response when adjacent to a boar than when tested in the home pen (Hemsworth *et al*. 1984). However, young females housed adjacent to boars appear to habituate to boar stimulation, showing shorter duration of oestrus behaviour and reduced response to a back pressure test during oestrus (Hemsworth *et al*. 1984, 1986, 1987, 1988; Tilbrook and Hemsworth, 1990). A similar effect on duration of detected oestrus was observed with multiparous sows (Dyck, 1988; Hemsworth and Hansen, 1990) although weaning to oestrus interval, farrowing rate and litter size were unaffected.

Both small (3 v >9) and large (24 v 8) group size can have detrimental effects on oestrus expression in gilts (Christenson and Ford, 1979; Cronin *et al*. 1983; Christenson, 1984). Gilts housed in pairs had a sustained increase in free corticosteroid concentration, and were more active than those in a group of 4 or 8, but this was not associated with any adverse effect on expression of sexual behaviour (Barnett *et* a*l*. 1986). Gilts housed at reduced space allowance (1, 2 or 3 sq m/gilt) also showed a sustained increase in free corticosteroid, but this was associated with reduced expression of oestrus behaviour (measured as a standing response to a back pressure test in the presence of a boar) which appeared to be due to an increased incidence of silent oestrus rather than failure to ovulate (Hemsworth *et al*. 1986).

The extent to which individual or group housing of sows in the service house is desirable will depend on the consequences of regrouping sows, since the majority of animals are currently individually housed during lactation. Whilst many chronic environmental stressors (e.g. long term housing and handling treatments) have been shown to affect reproductive performance in the pig (Varley and Stedman, 1993), effects often associated with chronic elevation in cortisol levels, the effect of acute social stressors is less well documented. An acute adrenal response to grouping in ovariectomised gilts was recorded, but disappeared within 24 hours although elevated morning cortisol levels were subsequently seen on days 2 and 3 after mixing (Barnett *et al*. 1981). Similarly, regrouped weaned sows showed elevated cortisol levels only on the day of grouping, and to a similar extent in sows of all social rank within the group of three (Pedersen *et al*. 1993). Measures to ameliorate the adverse welfare consequences of aggression include provision of *ad libitum* food, adequate space and possibility of visual isolation within the pen (PWAG, 1995).

In the study of Pedersen *et al*. (1993) social rank had no significant effect on any reproductive parameter, although the sample size was very small (3 replicates) and total received aggression was significantly positively correlated with weaning to oestrus interval and significantly negatively correlated with duration of oestrus. Animals had been individually housed in the previous pregnancy, which may have affected the response to grouping. A relationship between social rank and oestrus behaviour was found, with only sows of high social rank showing increased mounting and primarily sows of middle social rank showing increased levering during oestrus. Low ranking sows showed significantly less social behaviour at this time, suggesting that oestrus detection in these animals might be more difficult. In contrast, Pritchard *et al*. (1997) comparing groups of six sows familiar with group housing from previous pregnancies, failed to find any relationship between social rank (the proportion of encounters lost) and the expression of any oestrus and mating behaviours.

It is known that a particularly stress-sensitive stage in pig reproduction is the implantation phase, when hormonal perturbation can increase embryo mortality and hence reduce conception rate and/or litter size. Sows moved from the service house into pregnancy group housing at 17 days after entry (approx 10 days after first service) had a higher return rate and lower litter size than those moved after 10 days or 31 days (te Brake and Bressers, 1990). Similarly, in a large scale (345 cycles) study of performance of sows housed in dynamic groups in unbedded accommodation, return rate doubled when sows were introduced to the new group at 1-8 days post mating, compared with 22-29 days, although no large effect on litter size was seen (Bokma, 1990). Simmins (1993) reported results from a comparison of sows moved into either stable or dynamic groups within 7 days of mating, on average at 2-3 days after mating. Litter size was substantially lower for those entering the dynamic group, although this difference was not significant with the sample size of 170 sows. In a large scale comparison of sows transferred into groups at weaning with those initially housed in stalls and grouped after 4 weeks, it was found that grouping prior to the implantation period resulted in a reduction in litter size of 0.6 piglets although conception rate was not affected. Subsequent work examining grouping immediately after service or at four weeks also indicated detrimental effects of grouping before implantation, although no data were presented (Danske Slagterier, 1995). Farm survey data have failed to substantiate consistent detrimental effects on reproductive performance of group housing in comparison with stall housing. Examination of data from the 2 largest UK national recording schemes, operated by Easicare (PIC, 1996) and MLC (MLC, 1996), collected between 1990 and 1995 shows no consistent picture (Arey and Edwards, unpublished). Farm surveys often confound many management factors. More controlled within-farm, but large scale, studies have shown no difference in litter size or farrowing rate between individual and group housed sows (den Hartog *et al*. 1993; 1996).

It can therefore be concluded that the aggression which occurs during mixing does result in physiological stress responses, but the short term nature of the stressor means that, provided it does not occur at a critical time in the reproductive cycle, detrimental effects can be avoided.

5.1.2 The mating area

In a comparison of boar pens (used for both housing and service) which had flooring of either concrete slats or deep litter, no differences in conception rate or litter size were found (Udesen and Mikkelsen, 1989). Service conditions were rated as better in the deep litter pens, with fewer skids, fewer short matings (<2 minutes) and more longer matings (>5 minutes). No differences in boar durability were seen.

Allowing mating to take place in the boars home pen (1.9 x 2.2 m) resulted in fewer successful copulations than when a specially designed mating area (octagonal, minimum width 2.8 m, total area 10.5 sq m) was used (Hemsworth *et al*. 1989). Potential problems for boar welfare when mating occurred in the home pen were identified as limited area with sharp corners, slippery floors, mesh walls and protruding drinkers, which could cause pain or injury during such activity. Petchey and Hunt (1990) calculated from measurements of the body dimensions of sows and boars that a mating area would ideally provide a linear dimension of 3.9 m to allow a large sow (1.9 m body length) and boar (2.0 m body length) to stand nose to tail during the courtship procedures. Pens with a diagonal length of less than this dimension were generally considered unsatisfactory by stockmen in a farm survey in Scotland (Petchey and Hunt, 1989). Specially designed mating facilities have been developed to maximise stimuli to the male and female, and to provide optimal mating pen conditions (Hemsworth *et al*. 1991) but this design involved stall housing of the boars.

The use of group-mating systems, in which a team of boars are placed with the weaned sows and mating takes place without significant supervision, has also been investigated. In this situation, mounting efficiencies (copulation:mounts ratio) were <10% for most boars, although this was attributed to inadequacies in pen design and fighting among boars for access to sows was never observed (Tanida *et al*. 1989). Within the group, non-random selection of mating partners was observed, and some oestrus sows remained unmated (Tanida *et al*. 1989, 1991). Whilst mating systems involving groups of boars housed together are still relatively uncommon in indoor production, this is the most common method used in outdoor production. Survey data have consistently shown poorer reproductive performance in outdoor units than in indoor systems (e.g. Easicare, 1995). A detailed study of this system (Shaw and Edwards, 1995) found that the number of successful matings per sow varied from 0-7, while the number of matings performed by individual boars over the peak 4 day oestrus period varied from 0-13. Of the 45% of all mating attempts which failed to achieve copulation, half were due to intervention of a second boar. In the survey of outdoor herds by Easicare (1995), 80 herds using outdoor group mating with 3 or more boars/group had an average farrowing percentage of 73%, 18 herds using outdoor mating with 1-2 boars achieved 75%, whilst herds adopting indoor mating achieved 79%.

The dynamic service system is a variant on group mating which has been recently developed in Denmark as a means of overcoming the problems experienced in the existing outdoor group mating systems (Goss, 1996). Newly weaned sows are initially grouped in their weekly batch with *ad libitum* feeding. As they come on heat, they are transferred into one of a number of large dynamic groups according to body size. Each of these groups contains a resident team of boars (2-4 boars depending on the scale of operation) and the number of sows added weekly is such that a 1:1 ratio of sows on heat to boars is maintained in each group. Service takes place within the group, and the sows remain until late pregnancy (typically 9-11 weeks after service depending on individual farm circumstances). At this time, they are regrouped back into contemporary farrowing groups, and elevated late pregnancy feeding levels can be applied. Whilst the concept of mixing at the time of service and implantation has generally been advised against, this system has features which would seem to overcome many of the anticipated problems, and offers a better social environment for the boars. Whilst most experience of the dynamic service system to date has been in outdoor herds, a significant number of units have now adopted the system in straw courts. Early performance results and subjective assessments of welfare have been good, but detailed objective welfare assessments of this system have only recently begun, and no scientific results are yet available.

5.1.3 Artificial Insemination (AI)

Artificial Insemination is a very widespread practice within the EU. There is no specific information on welfare aspects of the practice of artificial insemination. Provided that semen collection and insemination procedures are carried out by trained and competent persons, who handle the boar and sow in an acceptable way (see section 4.6) and conform to good hygiene practices, there is no reason to believe that any detrimental effects on welfare will occur.

5.1.4 Conclusions

62. The mixing of mature boars can cause severe welfare problems due to damage during fighting.

63. The mixing of unfamiliar sows may cause welfare problems because of fights between the animals.

64. Recommendation: Neither boars nor gilts should be reared in social isolation. It is acceptable to house boars individually, but they should not be permanently housed in visual and olfactory isolation from other pigs. The dimensions of individual pens for mature boars should correspond to the weight and size of the pig. The mixing of mature boars should be avoided and carried out only when essential, and under close supervision. Mixing of unfamiliar sows will be necessary if group housing systems are adopted. The immediate post mixing period should be supervised and methods to minimise aggression should be applied.

65. Mating in a confined space where the sow cannot escape the courting attempts of the boar may cause welfare problems.

66. Recommendation: Mating areas should be smooth-sided with non-slip flooring and have a minimum diagonal length of 3.9 m. Mating should be supervised if it takes place in a confined space where the sow cannot escape from the boar.

67. Semen collection and artificial insemination procedures have potential risks for causing injuries and infections to the genital tracts of the animals.

68. Recommendation: Semen collection and artificial insemination procedures should be carried out only by trained and competent persons.

5.2 Dry sows

The quality of stockmanship has a considerable influence on pig welfare and hence on the results of studies comparing welfare in different systems. Poor stockmanship can lead to poor welfare in any system. Where one system is a little more difficult to manage than another, a relatively poor stockman might manage the second effectively but not the first. A very complex system might be very good if managed well but too difficult for 90% of pig farmers to manage. However, since pig farmers have become more and more able to deal with complex systems, there are systems used now which are more complex than those used in former years. Experimental comparisons should be done using good examples of systems and high levels of management. If necessary, trials on farms where management is less good could follow. Recommended systems should be manageable by the average farmer but if a substantial proportion of farmers would find the system difficult to manage, an alternative should be recommended.

The point (made above) that comparative studies of systems should utilise good examples of the systems is important but many research workers have been limited in their ability to do this. For, example, when a new system is first tested, it is unlikely that the system is fully developed at that point. Early problems are likely to be overcome in later versions of the system. When stalls were first used there were problems with the floors but these were improved in design and quality to reduce foot problems. Group-housing systems have had a shorter development period. The first electronic sow feeders were poorly designed in that they had a rear exit so that the sow had to back out into any group of waiting sows. Also, it was not known initially that multiple feed drops during a day tend to exacerbate problems at feeder entrances. Many pig farmers prefer the system which they know and hence are critical of new systems during their development stages but others try out new systems, sometimes before they are adequately designed. Hence farmers can have various prejudices about systems.

A further problem for those comparing systems is that there may be variation in animal welfare within a system which does not vary much in terms of production. Early studies of the welfare of tethered sows (e.g. Barnett *et al.* 1987) indicated that, using adrenal activity measures, sows in tethers in which aggression was possible between animals in adjoining tether places had considerably higher responses than those in tethers where aggressive interactions were minimised by barriers between the heads.

Until recently, comparisons of systems involved just production measures such as weight gain and piglet production. These measures can be indicators of poor welfare but for welfare assessment a wide range of measures, including those of behaviour, physiology and health should be used. The systems referred to in the comparisons discussed here are described in Section 3.2 of this Report.

5.2.1 Studies of preferences

Sows show strong preferences for certain resources and for possibilities for carrying out particular behaviours. Where the strength of preference can be assessed by observation and experiment we can discover what is important to the animal. Deprivation of something which is important to the animal makes the welfare of the animal worse. This occurs because of: firstly, the inability of the animal to carry out normal biological functioning and to control its interactions with its environment and secondly, any direct adverse effects of a lack of resource. However, as discussed in Chapter 2, animals' preferences do not always indicate what is best for them so care must be taken in interpretation of preference studies. Sows show strong preferences for food, water, social companions and the avoidance of danger. They also devote time and energy to exploring their environment and seeking diversity in that environment (Jensen 1980, Stolba and Wood-Gush 1989, Wood-Gush *et al.* 1990). They root in earth and manipulate materials such as straw; pigs will work for access to earth and bedding for manipulation as well as for lying (van Rooijen 1980, 1981, 1982, Hutson and Haskell 1990). Matthews and Ladewig (1994) produced demand curves for access to bedding materials and found that they were second only to food in the extent of the demand. It is clear from such studies that sow welfare will be worse in conditions where exploration of a complex environment, rooting in a soft substratum and manipulation of materials such as straw are not possible, than in conditions where they are possible.

When sows are put into a very small pen, they indicate by their behavioural responses that they find the confinement aversive. If given the opportunity, they leave the confined space and they usually resist attempts to make them return to that place. If moved on the farm after spending some time in a stall or tethered, sows attempt to move around and investigate open spaces rather than doing what the person moving them wants them to do. This is a rebound effect (Bogner 1984, Nicol 1987) where behaviour which has been prevented for some time is shown to a large degree when the opportunity arises. Direct studies of preferences for pens of different sizes are somewhat difficult to interpret, because a pig offered small or very small pens may find neither of them attractive, but Phillips *et al.* (1992) did report that sows chose wider rather than narrower crates in a preference study. In general, sows prefer not to be confined in a small space.

Sows prefer to have social contact with other pigs and they associate and interact in a friendly way much more than in an aggressive way (Wood-Gush *et al.* 1990) when provided with sufficient space and environmental complexity. They also synchronise various aspects of their behaviour including feeding. Hence it is easier for them to adapt to feeding regimes where all are fed simultaneously. Food is presented simultaneously to all sows in well designed stalls and feeding stall systems but adaptation to electronic sow-feeders is better if other, perhaps low energy, food sources are provided.

Sows show strong preferences to avoid other sows which might attack them. Group-housed sows may spend much time in places where attack likelihood is minimised and usually avoid actions which increase the likelihood of catching the attention of or provoking another sow which is recognised as being dangerous (Jensen 1980, Hunter *et al.* 1988, Mendl *et al.* 1992). The consequences of this for the design of sow housing are that sows should have an opportunity to hide from or otherwise avoid those individuals which might attack them and sow management should be such that the likelihood of attacks is minimised, for example by keeping groups stable. If sows are frequently attacked, they may prefer to be in an individual pen, at least for as long as the danger of attack persists.

5.2.2 Stereotypies and other abnormal, non-social behaviour

The most frequent abnormal non-social behaviours which have been reported in studies of the welfare of sows in relation to their housing and management, are stereotypies and apathetic, unresponsive behaviour. As discussed in chapter 1, stereotypies indicate that the individual is having difficulty in coping with its environment and hence that its welfare is poor. The extent of stereotypy gives an indication of how poor the welfare is. Similarly, welfare is also poor in individuals which are abnormally inactive, depressed and unreactive to stimuli which would normally elicit a reaction. Here too, the severity of the effect on the individual, and hence the extent of poor welfare, can be quantified.

Stereotypies such as bar-biting, sham-chewing, drinker-pressing, head-weaving, repeated patterns of nosing in a trough and tongue-rolling have been reported by many authors as occurring in many sows confined in stalls or tethers. Such behaviour is extremely rare in sows kept in complex environments but it does occur, usually at low incidence levels in some sows kept in groups, especially when the amount of food available is low and no manipulable material is provided. Bar-biting cannot be shown in circumstances where there are no bars but other stereotypies which could be shown are not shown. Sows kept in fields may chew stones, particularly when food availability is limited but it is not clear that this behaviour is stereotyped. In general, stereotypies are a characteristic behaviour of sows confined in a small space, typically in stalls or tethers, with little complexity in their environment and little possibility for the sow to regulate her interactions with all aspects of her environment.

The number of animals in a housing condition which show stereotypies and the proportion of time that stereotypies are shown have been the two measures used most frequently for describing the severity of abnormality in this behaviour. The figures for sows in complex environments where the sow can exercise, manipulate materials or root and interact socially are close to zero for both measures. The actual values obtained in a study of stereotypies in confined sows depends upon the method of recording, the time that the animals have been confined, the presence of manipulable material and the diet of the sows. The method of recording is important because sham-chewing, often the most prolonged stereotypy, was not recorded in some studies and very prolonged stereotypies lasting for more than 10 seconds before repetition are often missed by those who sample briefly. Sows which are confined show few stereotypies in the first few days, since they spend more time trying to escape at this time, but several studies have shown considerable increases in the incidence of stereotypies with time confined. Stolba *et al.* (1983) Cronin and Wiepkema (1984), von Borell and Hurnik (1991) and Broom *et al.* (1995) reported considerable increases in stereotypies with increasing parity but Terlouw and Lawrence (1993) found such increases in some stereotypies and conditions but not in others. The effects of manipulable material and of high levels of energy intake are to reduce the levels of stereotypies (Fraser 1975, Appleby and Lawrence 1987, Terlouw *et al.* 1991 a,b).

Bearing in mind the variety of factors which affect the extent of occurrence of stereotypies, it is not surprising that the level of occurrence varies between farms, between studies and between individuals within a study. Cronin (1985) found that 100% of 117 tethered sows showed stereotypies whilst Rushen (1984) described 20% of 30 sows studied as doing so. The amount of time spent showing stereotypies by sows in stalls was 22% (Jensen 1980, 1981, 1988) 11% (Broom and Potter 1984), 10-14% (Blackshaw and McVeigh 1984) and 14-50% (Broom *et al.* 1995) of observation time. Tethered sows showed stereotypies for 1.8-28% (Carter and English 1983), 15% (Bengtsson *et al.* 1983), 14.5-29% (Blackshaw and McVeigh 1984 a, b) and 39% (Cronin and Wiepkma 1984). However, in every detailed study of sows in stalls or tethers, a substantial level of stereotypies has been reported indicating poor welfare in the sows.

The effect of the provision of straw in reducing the incidence of stereotypies in confined sows was reported by Fraser (1975). This effect seemed to be a consequence of the possibility to manipulate straw since it was not apparent when the straw was chopped. The possibility to eat largely non-nutrient material which fills the gut but does not take long to eat did not have much effect on the occurrence of stereotypies in a study by Potter and Broom (1984). They found that feeding oat hulls which doubled the mass of food eaten and prolonged daily food intake time by 10-15 minutes had no effect on total time showing stereotypies but increased lying time and hence led to relatively more sham-chewing and less bar-biting. However Robert *et al.* (1993) did find an effect of dietary bulk on the incidence of stereotypies. In a study by Brouns *et al.* (1994) using supplementary sugar beet pulp which has some nutrient value, but which also affords some extra opportunity for chewing food, both bar-biting and sham-chewing were reduced. Large changes in energy intake resulting from the provision of 4 kg of concentrates instead of 2.2 kg led to considerably less stereotypy in both tethered and group-housed sows in a study by Terlouw *et al.* (1991). It would seem that the group-housed sows were disturbed by their housing conditions in this study because stereotypies generally occur at rather a low level in group-housed sows even at 2.2 kg of concentrates per day. Broom *et al.* (1995) reported maxima of 8% of time showing stereotypies or partly stereotyped behaviour in fourth parity sows kept in small groups and 4% in sows in a group with an electronic sow feeder, as compared with 50% in stall-housed sows. The increase of more than ten-fold in stereotypies in stall-housed sows from the early part of the first parity to the fourth parity is not paralleled in group-housed sows and is unlikely to be a consequence of feeding level since this was 2.2 kg, in all conditions following normal commercial practice. The incidence of stereotypies in stalls might have been reduced by the provision of straw because Spoolder *et al.* (1997), like Fraser (loc.cit) found that sows showed a lower incidence of stereotypies when straw was provided. It seems that the main effect of low feeding levels in sows is to exacerbate the effects of inadequate environmental conditions resulting in higher levels of stereotypies. Sows are frustrated and have difficulties in coping when they are confined and when food levels are low but especially when both problems exist.

In all studies of stereotypies in sows, three factors must be taken into account. One is whether or not they are confined in a stall or by a tether, the second is the level of energy providing food which is available to them, and the third is the presence or absence of manipulable material such as straw. The amount of freedom and the design of the stall or tether can also have some effect. These three factors are interactive in their effects. The worst condition for the sow, as judged by the extent of stereotypies, is to be confined in a stall or tether, to have a level of feed which is below that required for body and foetus maintenance and growth, and to have no manipulable material present. If the food level is increased to that typical of dry sow production systems, the extent of stereotypy may be reduced by a small amount. If food level is doubled it can be reduced further but such a change is very unlikely to occur in commercial pig production. In order to avoid the welfare problems which are indicated by this measure, the sows must not be confined in a stall or tether, they must be given enough high energy food for body and foetus maintenance and growth, and must have some bulky food and manipulable material available to them.

The existence of apathetic behaviour in some sows was pointed out by van Putten and Dammers (1976). A parallel can be shown with depressed behaviour in humans and learned helplessness in a variety of species (Seligman 1975). Since inactivity and unresponsiveness are the measurable aspects of apathy, this abnormal behaviour is open to measurement (Wiepkema *et al.* 1983). In studies of sows in stalls and in groups, Broom (1986, 1987) measured their responses to food, and to controlled novel stimuli. The sows in stalls responded readily to food but were much less responsive to other stimuli than were the group-housed sows. This abnormal inactivity and unresponsiveness in confined sows is very widespread. Most authors who have measured confined sow activity levels have reported that, with the exception of some very high stereotypers, they are very low (e.g. 12% Vestergaard 1984) in comparison with sows in environments where they have opportunity for exercise and exploration (e.g. 56% of time active Wood-Gush *et al.* 1990). Farmers often comment that their stall-housed or tethered sows are lying for much of the day. Since the extent of the inactivity and unresponsiveness indicates abnormal behaviour, the sows may well be depressed in the clinical sense and poor welfare is indicated. Some sows show this abnormal behaviour as an alternative to stereotypies and there are brain correlates of both of these types of abnormal behaviour (Section 5.2.5).

When sows are confined in stalls and tethers, the associated lack of exercise has consequences for muscle mass and bone strength (Marchant and Broom 1996a) and for behaviour. Schmid and Hirt (1993) demonstrated that sows restrained whilst growing chose to lie down whilst leaning against a wall on 77% of occasions as compared with only 3% of occasions for sows loose-housed during growth. The time taken by sows to lie down was 20 seconds in stall-housed sows but only 9 seconds in group-housed sows and the duration of lying was associated with the proportional weight of the extensor carpi radialis muscles (Marchant and Broom 1996b). These stalls were 2.2 x 0.6 m but in smaller stalls, lying problems would be greater. Confined housing leads to problems for sows in relation to these important movements and hence may affect the likelihood of squashing piglets after these are born.

5.2.3 Aggressive and other injurious behaviour

When sows attack one another they can cause considerable injuries and the welfare of the sow which is attacked will be poor because of fear during part or all of the period of the attack and because of pain from any wounds. As mentioned above, where attacks are possible sows will make efforts to avoid them and are clearly disturbed by the possibility of attack. Most injurious behaviour of sows is aggressive but the motivation for some of it may be exploration and manipulation.

Sows kept in stalls or tethers often show aggressive behaviour towards their neighbours (Barnett *et al.* 1987). Indeed the duration of aggression can be high, probably because the aggressive interaction cannot be satisfactorily resolved, and aggression was escalated to a high level more often and occurred in a higher proportion of agonistic interactions in stall-housed sows than in group-housed sows in a comparative study by Broom *et al.* (1995). Such aggressive interactions in confined sows will involve fear and frustration but normally no injury. They can be reduced by putting solid partitions between the animals in the region of the trough.

Sows in group-housing conditions can injure one another as well as causing fear and anxiety. The extent of fighting which occurs in groups of sows depends on group size, management methods and design of the housing system (Edwards and Riley 1986, Hunter *et al.* 1988, Edwards *et al.* 1993). Sows in pairs may fight and one individual can be severely affected (Barnett *et al.* 1986) and sows in larger groups with a larger and more varied space generally fight less than sows in smaller groups (Mendl 1994, Broom *et al.* 1995). In groups of 100 or more, subgroups may form but this need not cause problems (Edwards

1991). Fighting can occur at feeding and at times of social mixing (see Section 4.2). For group-housed sows, food spread widely over a large area results in less fighting than food concentrated in a small area but at normal densities of housed sows some fighting will occur with floor feeding. Feed troughs with partial barriers between sows reduces aggression (Petherick *et al.* 1987) and feeding in individual feeding stalls reduces fighting at this time to a very low level. Trickle feeding ("Biofix") in which sows feed slowly from individual feeding points also reduces fighting effectively. Electronic sow feeders ensure that sows wearing responders or transponders receive the allocated amounts of food but the design of building and frequency of feeding affects the extent of fighting. Sows will queue behind the feeder so unless the sow in the feeder can leave by a front exit, she may be bitten as she leaves. In circumstances where there is substantial competition for food, sows may be attacked and bitten elsewhere in the pen. The feeder should be located in such a way that there is much space around the entrance and exit and little likelihood of sows lying in either place or in the feeder itself. If food is available on several occasions during a 24 hour period, sows spend much time waiting at the feeder entrance and fighting may occur there. Hence, restriction of food availability to one cycle of feeding per day means that sows learn this and are less likely to stay close to the feeder entrance. An additional problem results from receiving food in several small feeds because on each occasion that the sow feeds she will not be satisfied with the amount received so there will be more times when unsatisfied, potentially aggressive sows are present. With a single, larger feed the level of satisfaction is likely to be higher so the overall frequency with which sows are aggressively motivated because of feeding but being unsatisfied will be substantially reduced. A further action which can help to reduce aggression related to food is to provide some other source of low density food such as straw, sugar beet pulp, oat hulls etc.

Whatever the method of feeding, some aggressive behaviour can occur when new sows are mixed into a group, although the problem is exacerbated at feeding time if food competition occurs. Problems at mixing can be minimised by having sufficient space and sufficient possibilities for hiding behind walls, feeders, other environmental features or pigs. Mixing gilts in a small pen with a high density ($1.4m^2$ per pig) also causes less aggression although the level of cortisol is high (Barnett *et al.* 1993a). The presence of a boar at mixing can reduce aggression in some circumstances (Barnett *et al.* 1993b) but not in others (Luescher *et al.* 1990) and boar odour alone did not prevent aggression by gilts in a study by Parrott *et al.* (1985). Mixing during darkness does not solve the problem (Barnett *et al.* 1994) and although sleep inducing drugs such as amperozide may reduce aggression they can have other adverse effects (Barnett *et al.* 1993b). In general, gradual mixing of small groups into a large group is more like what happens in wild boar groups (Mendl 1994). Where sows must be introduced to a group of 20 or more, the introduction of a group of 4-6 sows results in less fighting than introduction of the animals one at a time or the introduction of a group of 10 or more (Hunter, E.J. unpublished report). Mixing of sows with a period of prior exposure to the mixing group in a pen separated by an open gate can reduce aggression after mixing considerably (Kennedy and Broom 1994) and exposure of the main group to the bedding odour or the sounds of the introduced group also reduces aggression (Kennedy and Broom 1996).

Where systems with and without straw or other materials have been compared, the results have been somewhat variable according to the feeding methods and the stability of the group. Petermen *et al.* (1995) reported fewer behaviour disturbances if straw and branches were provided and Arkenau *et al.* (1996) found that straw reduced aggression in group-housed sows but Krause (1995) did not find any reduction in bite injuries if straw was available in a rack for sows on slats.

Many farmers can successfully manage sows in group-housing systems without much aggression provided that the group is kept relatively stable, in that sows return to the same group after farrowing and new animals are brought in only when necessary, mixing is managed carefully, the feeding system minimises competition situations and there are adequate degrees of environmental complexity and alternative low density food source. A facility for keeping sows individually if they are sick or the subject of severe aggression is necessary (see 5.2.1).

5.2.4 Adrenal and other physiological measures: body and brain

When sows are disturbed and preparing for or carrying out emergency actions the levels of ACTH, ß-endorphin and cortisol in plasma and other body fluids increase. The response is not long lasting and the high cortisol levels found after the tethering of gilts decline to the basal level within 24 hours of tethering (Cariolet and Dantzer 1985). However the cortisol response can be repeated and its frequent use monitored using CRH or ACTH challenge. More active, as well as more disturbed, animals may show increased adrenal activity. As a consequence of these characteristics of the adrenal response, some comparisons of sow housing conditions show differences in adrenal activity but others do not. Barnett *et al.* (1981) found a higher cortisol level in individually penned than in group-housed sows and the level was nearer to the maximal cortical binding capacity in the individually penned sows. In a series of studies, Barnett, Hemsworth and collaborators found higher cortisol levels in tethered or stall-housed sows than in group-housed sows (Barnett *et al.* 1984, 1985, 1986, 1987a, b). The highest cortisol levels were in tethered sows where head contact between neighbours was possible at feeding and groups of 2 had higher values than groups of 3-8. Barnett and Taylor (1995) found that cortisol and cortisol response to ACTH was higher in tethered sows than in sows in a small group or a turn-around stall with a hinged side. Janssens *et al.* (1995a) found that tethering gilts increased cortisol levels and the cortisol response to ACTH for three oestrus cycles. Visually separated tethered gilts showed a more prolonged response, over 20 weeks, then gilts with full view of other pigs when ACTH challenge was carried out (Janssens *et al.* 1994). Using CRH challenge as well, tethering was found to increase the sensitivity of the adrenal cortex to ACTH (Janssens *et al.* 1995b).

Other studies of sow welfare using physiological measurements have related these measures to abnormal behaviour. Dantzer and Mormède (1981) found that chain chewing stereotypies were associated with lower cortisol levels in tethered gilts but Terlouw *et al*. (1991) did not find that high stereotypers amongst tethered sows had lower cortisol levels. Proposed relationships between stereotypies and dopaminergic systems (Sharman and Stephens 1974, Sharman 1978) might suggest that treatment of pigs with apomorphine or amphetamine could produce stereotypies like those caused during confinement but this has not been the case (Terlouw *et al.* 1992 a,b). Stereotypies clearly have parallels in brain processes but causal relationships are not simple. Possible links with opioid systems and ß-endorphin in particular, were suggested by Cronin's experiments with the opioid receptor blocker naloxone, which was found to inhibit stereotypies for a short period (Cronin and Wiepkema 1984, Cronin *et al*. 1985). However naloxone affects both mu and kappa receptors and a study by Zanella *et al*. (1996) linked stereotypies with kappa receptors, and hence dynorphin, rather than with mu receptors and ß-endorphin. Most of these studies provide information about the causation and effects of stereotypies but they do also indicate the extent to which physiological processes in the brain as well as the adrenals are involved in coping with confinement and other problems.

Abnormal inactivity in confined sows is not just associated with reduced responsiveness, as described in Section 5.2.2., but also with brain function. Zanella *et al*. (1996) found that mu receptor density in the frontal cortex of sows at slaughter was greater in sows which had been more inactive and greater in previously tethered sows than in previously group-housed sows.

5.2.5 Immunological and disease incidence measures

Whenever attempts to cope involve substantial adrenal cortex responses there is a possibility that immune system function will be suppressed and the same consequence may also parallel a variety of other behavioural and physiological coping attempts (Broom and Johnson 1993, p.121). Sows which produced a greater cortisol response to ACTH challenge also produced a lower titre of antibodies following antigen challenge (Zanella *et al.* 1991, Zanella 1992). In studies by Barnett *et al.* (1987 a,b), tethered sows were compared with group-housed sows and found to show lower immunoglobulin (Ig B and Ig M) levels after challenge with *Escherischia coli* K99.

If sows are exposed to infectious diseases such as Aujeszky's or swine fever, then all may become infected, irrespective of their previous welfare. Non-infectious, or less infectious diseases, such as those leading to some foot and leg problems, sores, torsion of the gut or ulcers, are more obviously related to environmental conditions and the animals' attempts to cope with them. On modern pig units where disease is controlled well, no systems of housing dry sows have substantial levels of disease and there are no major differences in disease incidence between the various systems for confined or group-housed sows.

Bäckström (1973) found greater total sow morbidity at farrowing in crate-housed sows (24.1%) than in loose-housed sows (12.8%) as well as greater MMA incidence. The quality of management has improved since these studies were carried out, however. Confined sows may also be more subject to urinary disease and leg problems, whilst group-housed sows are more likely to receive pig inflicted injuries and sometimes have higher parasite loads. Tillon and Madec (1984) noticed that urinary tract disorders had increased in frequency in France during a period when more and more sows were confined. They reported on the relatively high incidence of such disorders in tethered sows and (Madec 1984) suggested that sows might be more prone to urinary disorders if they have to lie on their faeces. They also found that tethered sows drink less and urinate less often than loose-housed sows, so that urine is more concentrated and bacteria have longer to act within the urinary tract (Madec 1985). This problem is probably a consequence of low activity levels and consequent infrequent drinking, hence whilst it could be in part a consequence of the effect of the housing system on the animal, it may be reduced within that system by stockmen encouraging the animals to stand and drink. There is clearly much variation among sows here, as some inactive sows drink infrequently but other active sows drink very often. Tillon and Madec (1984) also reported that in one quarter of tether units more than 20% of sows showed serious lameness. Several other authors have reported similar findings. These findings show that there is a greater risk of certain disorders in confined sows but careful investigation can sometimes identify the risk factors and minimise their effects.

5.2.6 Reproductive problems

Some sows are culled because they do not become pregnant and others have small litters. These reproductive failures or inadequacies can occur because the sow encounters and has to cope with difficult conditions. Many factors lead to anoestrus in the pig (Meredith 1982) but several authors have attributed anoestrus to housing conditions. Jensen *et al*. (1970) reported that tethered gilts reached first oestrus 4 days later than group-housed gilts, Mavrogenis and Robinson (1976) found even larger differences in the time of first oestrus between gilts in stalls and gilts housed in groups. Individual penning of sows can lead to fewer sows becoming pregnant after service, or attempted service, than group-rearing of sows (Fahmy and Dufour 1976). Sommer (1979), Sommer *et al*. (1982) and Hemsworth, Salden and Hoogerbrugge

(1982) also found that stall-housed sows returned to oestrus, after their piglets had been weaned, later than group-housed sows. However in commercial practice, such differences are not generally found. Maclean (1969) reported that in groups where much "bullying" occurred the opposite result was obtained and veterinary surgeons report that bullied sows can be late coming into heat. This clearly requires further study. Hansen and Vestergaard (1984) also reported that the delay before conception was greater in some group-housed sows. It may be that reproduction is impaired by poor welfare in the housing conditions but assessing such impairment will depend on the stockman's ability to detect signs of oestrus.

The effects of housing conditions on the onset and occurrence of oestrus should be studied in a way which controls all variables. Studies do suggest, however, that there are more problems when gilts or sows are kept in stalls or tethers than when they are kept in a well-managed group-housing system. Welfare can, of course, be poor in group-housing systems where fighting occurs and oestrus is consequently delayed. Other measures of reproductive problems may reflect poor welfare during the gestation period and problems at farrowing. Most studies are complicated by the fact that sow accommodation during both gestation and farrowing may influence the results. Bäckström (1973) compared 1283 sows confined in a crate during pregnancy and farrowing with 654 sows free in a pen at both times. In crate-housed sows there was a higher incidence of mastitis/metritis/agalactia (11.2% : 6.7%) and greater numbers of sows whose farrowing times were longer than 8 hours (5.4% : 2.3%). In more modern systems, however, MMA incidence is considerably less than that found by Bäckström. In another study, Vestergaard and Hansen (1984) studied four groups of sows which were tethered or loose-housed during pregnancy and during farrowing. The duration of farrowing was significantly shorter (mean 234 minutes) in those sows which were loose-housed throughout, than in those which were tethered at one stage or another (mean 335-352 minutes). It seems possible that lack of exercise has some adverse effect on the sow. There was no effect of the sows' housing conditions on the numbers of live piglets born but, since only 70 sows were studied, such a difference would have to have been large to be apparent. Bäckström (1973) and Sommer *et al*. (1972) did find more stillborn piglets if sows were confined but in some more recent studies there were no differences or differences in the other direction between confined and group-reared sows in the number of still born piglets (N-P Nielsen pers.) The duration of farrowing can be considerably shorter in modern sows than in those studied by Bäckström for example. Madec and Leon (1992), with the use of prostaglandins, reported a mean duration of 192 minutes and only 10% of farrowings took longer than 300 minutes..

When all sows in a housing condition are considered, the mean differences between conditions are found to be small but the effect on certain sows is large. There are problems for some sows from group-housing and for rather more sows from confined conditions; but we do not know enough about how this is brought about. On commercial farms which have well managed stall units, reproductive problems are no more frequent than on units with group-housing (Broom et al 1995, Signoret and Vieuille 1996, den Hartog et al 1996).. It must be emphasised, also, that in surveys such as that of Bäckström, there is a possibility that variation in unit size or in stockmanship may be contributing to the differences reported. In general, the coping systems of animals have evolved to minimise effects on reproductive success, so if there are differences between systems, even a small effect may indicate considerable welfare problems.

5.2.7 Body function and injuries

The effects of lack of exercise in sows which are tethered or in stalls is to reduce the mass of some muscles which are particularly concerned with locomotion so that several of these are smaller, in proportion to body weight, than in group-housed sows (Marchant and Broom 1996). As mentioned in Section 5.1.3., these changes affect ability to lie down. Lack of exercise also affects bone strength and stall-housed sows had leg bones which were only two thirds of the strength of those of group-housed sows. Although having weaker bones means that the animal is less well able to cope with its environment, sows seldom break their legs. Sows in both confined and group-housing conditions may have leg problems.

Bäckström (1973) found that the number of traumatic injuries caused by pen fittings and flooring was 6.1% in confined sows but 0.8% in loose housing. Most studies of leg injuries and infections which cause lameness have related their incidence to the type of flooring. de Koning (1983) utilised a precise method for quantifying integumental lesions and has reported that such lesions can be of high frequency in tethered sow units. It is clear from practical veterinary experience that lameness can occur in group-housing as well as in stalls and tethers but research results suggest that on well managed units with good flooring the problem may be worse amongst confined sows. If group-housing systems are not well managed, for example if the animals are fed high energy food more than once per day or if new animals are introduced frequently, there may be interactions which increase the chances of fighting injuries and leg injuries and this may explain some atypical results (e.g. den Hartog *et al.* 1996).

All of these effects of housing system on leg problems and leg weakness are significant because of any direct painful effects on the animal but also because weak bones or lameness mean poorer ability to cope with the environment and perhaps earlier death as a consequence. Christenson *et al*. (1995) reported that the commonest problem in sow mortality cases was leg weakness (28.5%).

Another consequence of lack of exercise in stall-housed and tethered sows is that they use their cardiovascular system less. This is significant in the situation where many pigs which die during transport are diagnosed as having cardiovascular problems. In a study of heart-rate responses to a feeding situation, Marchant and Rudd (1993) concluded that the level of cardiovascular fitness in stall-housed sows was less than that in group-housed sows.

Injuries can occur during fights or as a result of other situations where one sow bites another, and can be serious in group-housing conditions. Good management, for example, a good feeding system and the maintenance of stable groups, can minimise fighting and consequent injury but injury can have a serious detrimental effect on welfare in a poorly managed system. Where sows are attacked by others the lesion can be quantified in a precise way (Gloor and Dolf 1985). Any system for keeping sows which results in high levels of fights which cause injury, vulva biting or tail biting is clearly bad for the welfare of at least some of the pigs. den Hartog *et al*. (1996) found more skin lesions in sows kept in an electronic sow feeder system than in other systems. They also reported more leg problems. Both of these types of problem may be a result of inadequate design of system or management and the skin lesions were measured after mixing but they indicate that such problems can occur in group-housing. When new sows are introduced in a stall or tether house, although there may be aggression, there will not normally be injuries.

5.2.8 Growth and piglet production

It is possible that a gilt which fails to grow or a gilt or sow which produces very small litters of piglets may have a welfare problem although other factors contribute. In comparative studies of production systems, however, it is often difficult to discover how many individuals do badly in this way because the data are presented as a mean of all animals involved. Hence, a few pigs which produce well could mask a few bad producers. Where average production figures are used it is clear that well managed units can do equally well whether the sows are confined or in one of the forms of group housing. The quality of stockmanship, an important factor affecting production, will also have an effect on welfare. In general, data on growth and piglet production have not been presented in the agricultural literature in a way which facilitates the identification of individuals with welfare problems.

Growth of gilts was slightly less in stalls than in group-housing in one study (Broom *et al*. 1995) but in many other studies, no differences in gilt growth were reported. Farmers in the UK get good piglet production in well managed group-housing systems but some have reported better piglet production from confined sows. In a study by Broom *et al*. (1995) and in large scale studies by Signoret and Vieuille (1996) and by den Hartog et al (1996), piglet production was good from sows in confined and group-housed systems and there were no significant differences between systems.

5.2.9 Conditions for stockpersons

Confined sows are easier to manage than sows in groups. Hence the job of caring for these sows is more demanding if they are in groups and a few people may lack sufficient competence to be successful. This is relevant to sow welfare since poor management can result in problems for sows not being detected and remedied. However, most people are able to care for sows in groups and may be able to ensure efficient reproduction more easily.

5.2.10 Effects of dry sow housing on sow welfare during farrowing

Sows which had previously lived in a small crate are less disturbed behaviourally when they are put in a farrowing crate. Marchant and Broom (1993) reported less restlessness in such sows than in sows from an electronic sow feeder when put into a farrowing crate. Cronin *et al.* (1996) found that piglet mortality was higher when sows were put into a farrowing crate after group-housing than after individual housing during pregnancy. Sows moving from group-housing during pregnancy to group farrowing show no disturbance.

5.2.11 Summary and conclusions

69. Some welfare problems of dry sows can occur in several different kinds of rearing conditions. The food provided for dry sows is usually much less than that which sows would choose to consume, so the animals are hungry throughout much of their lives. Energy intake has to be limited in dry sows to prevent the detrimental effects of obesity, but too low a feed level causes very poor welfare. This problem can be alleviated by giving bulky food, and in some cases, this can also supply the need for manipulable material.

70. Recommendation: All sows should be given sufficient food for maintenance, growth and piglet production. All sows should be given some bulky or high fibre food as well as high energy food in order to reduce hunger as well as to provide for the need to chew. The high energy food can be fed once per day in a single meal but bulky or high fibre food should be available for longer periods.

71. The advantages for welfare of the confinement of sows in stalls over group-housing of sows are as follows; since pigs are not mixed, fighting with associated stress and injuries is prevented, each sow is certain to have the full ration of food available to her, sows can all feed at the same time, care-taking is made easier and signs of morbidity, such as feed refusals or vulval discharge, are easy to detect and can then be treated appropriately.
The major disadvantage of group-housing is that injuries such as bites to the vulva or skin can occur, and it is also possible for these sows to slip on the floor. Fighting or injury could lead to embryo loss in extreme cases, and detection of health problems is more difficult. In general, better stockmanship is necessary to prevent these adverse affects.

72. The advantages for welfare of group-housing sows rather than confining them in stalls are that: the sows have more exercise, more control over their environment, more opportunity for normal social interactions and better potential for the provision of opportunities to root or manipulate materials. The major problems evident in good examples of tether-housing are also evident in stall-housing. As a consequence, group-housed sows show less abnormality of bone and muscle development, much less abnormal behaviour, less likelihood of extreme physiological responses, less of the urinary tract infections associated with inactivity, and better cardiovascular fitness. The major disadvantages for sow welfare of housing them in stalls are indicated by high levels of stereotypies, of unresolved aggression and of inactivity associated with unresponsiveness, weaker bones and muscles and the clinical conditions mentioned above. Some serious welfare problems for sows persist even in the best stall-housing system.

73. Recommendation:** **Since overall welfare appears to be better when sows are not confined throughout gestation, sows should preferably be kept in groups. However, only housing systems resulting in minimal aggression or injury should be used. This can be achieved in a housing system meeting the following criteria: sows in groups should be fed using a system which ensures that each individual can obtain sufficient food without being attacked, even when competitors for the food are present. All sows should have access to soil for rooting or manipulable material such as straw. Housing facilities for dry sows and gilts should include communal lying areas, in addition to any feeding stalls or boxes, of at least 1.3 m^2 per sow (0.95 m^2 for gilts). Opportunities for escape and avoidance, such as can be provided by generous space or well designed partitions, should be available for sows, especially those newly introduced to a group. Systems such as this, which are working well in common practice, are available. Individuals which are sick or injured, or which have been attacked by other sows, may temporarily be kept in individual pens. No individual pen should be used which does not allow the sow to turn around easily.

74. The management of sows in groups requires careful monitoring of animals, good housing design and good stockmanship.

75. Recommendation: For all systems, groups should be kept as stable as possible, sows being returned to the same group after farrowing and new animals being introduced in small groups, e.g. 5. A facility for separating sick or injured animals from the group should be available.

5.3 Farrowing and lactation

Sows are usually kept in separate units from a few days before expected farrowing up to weaning. Since weaning times may vary from less than one week post partum (mainly in some intensive North American systems) to more than five weeks (e.g. in many Swedish herds), with a probable EU-median of 3-4 weeks, the time the sow and the piglets spend in the farrowing unit is quite variable.

From a welfare point of view, the systems used for farrowing and lactation may be divided into two main groups: sows kept in crates or loose sows. Both the categories comprise an array of different detailed solutions; there are crate systems with varying degrees of freedom of movement for the sow and loose-housing systems with variations in many details. An overview of the most common systems is given in chapter 3 of this report. In intensive pig production, crate systems dominate.

It may be fruitful to examine the welfare aspects for the sow and the piglets separately. Farrowing crates were introduced at least partly with the aim of reducing piglet mortality (Phillips and Fraser 1993), and mortality is an important welfare parameter. The welfare of the sow may be poor in a system that means good welfare for the piglets, and vice versa. It may therefore be impossible to envisage a housing system that maximises welfare for both sows and piglets simultaneously.

5.3.1 Piglet mortality - levels and causes

Since an obvious function of crate systems for sows is to reduce piglet mortality, it may be worthwhile to review the levels and causes of piglet mortality in intensive pig breeding.

The pre-weaning mortality of piglets is often reported to be between 10 and 20%; in Britain, it has gradually decreased from just over 15% in 1970 to just below 12% in 1994 (Varley 1995). In most surveys, it has been found that over 90% of the deaths occur during the first week of life (Varley 1995). A major risk factor for neonatal mortality is low birth-weight (below 1000 g) (Siemensen 1980).

Even if the mortality level of pigs is considerably higher than in other closely related domestic species (Varley 1995), it should be remembered that the pig is the only truly polytocous ungulate with litter sizes that greatly exceed those of other ungulates. There may be a "normal" baseline mortality in pigs, which may prove to be very difficult to get below. The fact that pre-weaning piglet mortality in Britain has not decreased during the last ten years may indicate that such a baseline exists. However, we do not know anything of such baseline levels, and since some pig herds have consistently lower mortality than average (about 5%) (Algers 1985, Friendship 1986) this shows that husbandry factors may be effective in reducing the mortality. Furthermore, mortality is not randomly distributed between sows; in one study, more than half the mortality was concentrated in only 17% of the litters, and it has long been known that some sows seem to be particularly prone to lose piglets (English 1975, English 1977, Fraser 1990).

The most-quoted cause of neonatal piglet mortality is crushing or over-lying by the sow. This can be a result of a variety of sow movements; for example the piglet may become trapped between the hindlegs of the sow as she lies down from a standing position, it may get crushed under the udder when the sow lies down from a sitting position, or may get under the sow as she rolls, for example in order to expose the udder before a nursing (Edwards and Malkin 1986, Fraser 1990). However, reviews of different studies where neonatal mortality has been analysed in detail, shows that less than 50% (in some studies less than 20%) of the mortality is primarily caused by crushing, whereas malnutrition is responsible for about an equally large proportion (Fraser 1990, Varley 1995). Therefore, in attempting to reduce piglet mortality, methods of facilitating the sow's milk production and milk transfer should be considered equally as much as methods to reduce crushing. It should also be remembered that surveillance during farrowing by the caretaker will have a major effect in reducing piglet mortality (Edwards and Malkin 1986).

5.3.2 Piglet nutrition and diseases

Since low birth weight is a very important risk factor for the newborn piglet, methods to increase the birth weight would be important in increasing the likelihood of piglet survival. Proper nutrition of the pregnant sow is one such method (present trends to breed for increasing litter sizes will however act against this, since litter size and piglet weights are negatively correlated) (Pluske *et al*. 1995). The relationship between the nutrition of the gestating sow and the birth weight of the piglets is most pronounced in multiparous sows, where many studies have indicated a steady increase in piglet birth weight with increased energy intake during pregnancy (in the range 12-45 MJ DE per day), whereas the relationship for gilts is only apparent when they tend to be underfed (in the range 10-30 MJ DE per day) (reviewed by Pluske *et al*. 1995) .

Colostrum intake during the first day of life is extremely important, since colostral antibodies are the first sources of immune protection to the pig (Holland 1990). The capacity to take up macromolecules from the intestinal epithelium is severely decreased at about 24-36 h of age (Ekström and Weström 1991). Failure to ingest colostrum will dramatically decrease the survival of the piglet (Svendsen 1992).

There are several important infectious diseases which may affect the neonatal piglet, most of them gastro-intestinal, such as Colibacillosis, *Clostridium perfingens* type C enteritis, Coccidiosis, Transmissible Gastroenteritis, and Rotavirus diarrhoea (Martineau *et al*. 1995). However, they are responsible for less than 27% of the total neonatal mortality and appear to be relatively independent of the type of housing system (Martineau *et al*. 1995, Varley 1995). It is important to take all possible measures to maintain a high hygienic standard in the farrowing unit and to reduce transmission of infections; such measures are equally important in all housing systems. Some systems may facilitate the maintenance of hygiene. Division of the buildings into smaller compartments, combined with a batch management system, facilitates cleaning and disinfection between batches, and perforated floors help in reducing the exposure of the animals to the dung.

5.3.3 Environmental effects on crushing of piglets

A number of experimental and epidemiological studies have been carried out in order to detect effects of farrowing environment on piglet survival. When splitting the accommodation grossly into crated and loose housed sows, most studies show a beneficial effect of farrowing crates on piglet survival, although the results are somewhat equivocal, with some studies showing no differences between types of systems (Aumaitre 1984, Cronin *et al*. 1996a, Fraser 1990, Gustafsson 1982, Phillips and Fraser 1993). The generality of the comparisons vary of course, since details in the design of the environment may vary considerably, but in particular crushing by sows seems on an average basis to be reduced by keeping the sow in a farrowing crate (Cronin *et al*. 1996b, Olsson and Svendsen 1989).

It appears that the main protective effects of farrowing crates are exerted in the first few days post partum, in that the inhibited movements of the sows reduce the incidence of crushing and over-lying (Fraser *et al*. 1995). Detailed recordings of the movements of crated and loose-housed sows have shown that the type of movements are altered by the design of the environment, and hence the type of crushing which occurs appears to be environment-dependent; for example, loose housed sows crushed more piglets through movements where the sow rolled from side to lying on the udder or vice versa, while crated sows crushed more piglets through movements from lying to sitting and vice versa (Weary *et al*. 1996). It should also be born in mind that even small variations in the design of farrowing crates, for example width between the tubes, or fingered or horizontal bottom bars, may strongly affect health and behaviour of both sows and piglets (Curtis *et al*. 1988).

Crushing and other causes of neonatal mortality are multifactorial. Variations between different herds with the same housing system may be large. In Sweden, farrowing crates were forbidden in the law of 1988. According to a continuous national voluntary survey of more than 400 average Swedish sow herds (the so called RASP-screening), the mortality from birth to weaning was 15.2%, 15.1%, 14.9% and 14.8% respectively in the years 1993-1996. The average for the best 25% of the herds in 1996 was 12.9%. This can be compared to the corresponding screening results from Denmark, where most sows are kept in crates, which show a mortality of 11.7% in 1847 screened herds during 1996 (the E-control) (Kerstin Anner, Swedish Farmers' Meat Marketing Association, pers.comm.). These data demonstrate that, under commercial conditions, many farms manage to run loose housing systems with mortality levels as low as, or lower than, many farms with farrowing crate systems but, on average, mortality is likely to increase if farrowing crate systems are replaced by loose housing systems.

It should also be remembered that low incidences of piglet mortality have been recorded in prototype systems with completely loose-housed, and sometimes group-housed, sows where the systems may provide very little physical protection for the piglets (e.g. no rails or protecting gates and no creep areas); such systems have been in limited practical use, and most experience comes from experimental set-ups. However, also under practical conditions on a limited number of farms, similar results have been reported (Algers 1991, Schmid 1993).

5.3.4 Environmental effects on other causes of piglet mortality

The size of the weaned litter depends on four different factors: number of fetuses at the start of pregnancy, number of fetuses surviving up to the start of farrowing, mortality during the birth, and pre-weaning mortality.

The number of fetuses and their survival during pregnancy appear to be closely linked to genetic factors, and there is a considerable variation between breeds in these factors (Blasco *et al*. 1993). There is also a clear effect of the sow's nutritional status during the pregnancy (Pluske *et al*. 1995), but otherwise there is little knowledge of the effect of possible environmental factors.

Mortality during farrowing is more common in the later parts of each parturition, and appears to be caused mainly by interruptions of the fetal supply of oxygen; it is more prevalent in prolonged farrowings (more than 6 h) and in piglets being born after a longer than normal interval (Fraser *et al*. 1995). Even if there is a lack of knowledge about the causes of long farrowings, a Swedish epidemiological study demonstrated that long farrowings (in this study, >8 h) were almost twice as prevalent in sows kept crated during pregnancy and lactation compared to sows kept loose (Bäckström 1973). This is in agreement with Swiss studies, where farrowing times, on average, were 237.9 min in crated sows compared to 170.1 min in loose housed sows (Weber and Troxler 1988). The Swiss authors concluded that the difference was attributable to the fact that nest building was inhibited in the crated sows. Bäckström (1973) also reported that the incidence of stillborn piglets was higher in sows kept in crates during farrowing and that had been confined during pregnancy. There is a lack of recent surveys of the same magnitude as the one of Bäckström, and it should, of course, be kept in mind that both quality of husbandry and genetic characteristics have undergone considerable changes during the time since these studies were performed.

Taken in total (5.3.4 and 5.3.5), available data indicate that crating of sows may possibly have a negative effect the number of live-born piglets by increasing the mortality during birth through prolonged farrowings, but is likely to decrease the farrowing-to-weaning mortality through reducing crushing incidences. Crushing of new-born piglets is by far the most pertinent welfare problem from the piglet perspective. As shown by production data in Sweden, loose house systems may work with a low piglet mortality. However, Danish studies where different loose house systems for farrowing sows have been compared show that the piglet losses during lactation may be considerable in these systems, in particular if they are not skilfully operated (Niels-Peder Nielsen 1996; Unpublished report from "Danske Slagterier", Meddelelse nr 329).

5.3.5 Environmental effects on sow behaviour

The most prominent behaviour of the pre-parturient free-ranging sow is increased locomotion and nest building (see Chapter 2). Of course, if sows are crated during the period around farrowing, this behaviour is thwarted.

The expression of these behaviours seem to be hard-wired into the neural system of the sow and, even in the presence of a pre-constructed nest, sows will perform them (Arey *et al*. 1991). If the sows are loose housed, with no nest material present and no substrate to manipulate, they will go through the motions of nest building in a similar sequence and with similar frequencies to sows in enriched pens with straw and soil (Jensen 1993). Sows which are crated attempt to perform the motions as well, and show increased activity and increased frequencies of stereotyped movements during the period when they are motivated for nest building (Baxter 1982, Cronin *et al*. 1996b, Lammers 1986). In a demand-experiment, sows showed a strong but short-lived motivation to perform operant responses in order to get access to nest building material and opportunities to nest build, and in general showed signs of increased motivation to perform nest building (Haskell and Hutson 1996, Hutson 1992).
When given choices between different types of farrowing crates, sows have been found to prefer crates wide enough to allow them to turn around (Phillips *et al*. 1992). However, also the relative seclusion of the nest site and straw seem important, and may modify the preferences of the sow (Petchey *et al*. 1993). Although details of the construction of the farrowing crate may have large effects on the health and production of sows and piglets, the width of the crate seems to be the most important factor for the behaviour of the sow, where sows in more narrow crates are more restless (Curtis *et al*. 1988).

Some experiments have elucidated the physiological basis for the onset of nest building behaviour. In one study, prolactin was the only hormone which consistently correlated with nest building onset in prostaglandin-induced farrowings, which suggests an important causal function for this hormone (Widowski *et al*. 1990). However, as noted by Lawrence and co-workers, sows sometimes perform the full nest building activity without previous rise in prolactin concentrations, which indicates that prolactin can not be the only internal factor responsible for the onset of the behaviour (Lawrence *et al*. 1994b).

Summing up the evidence, it is beyond doubt that there is an internally triggered need to perform nest building behaviour in the pre-parturient sow (during the last 20 h or so before farrowing). Some of the nest building activities may be possible for the sow to carry out in a farrowing crate, in particular if the sow is offered straw, but a large part of the normal behaviour patterns are inhibited by the physical limitations of the crate. In crates, details of the pre-parturient behaviour of sows may be different when comparing different types of crate construction, but all farrowing crates are similar in that they obstruct the full expression of normal nesting behaviour (Curtis 1995).

5.3.6 Environmental effects on sow health

Effects of crating on sow health will, of course, depend to a large extent on how long the sow is kept crated. For example, in a Swedish survey study, total morbidity at farrowing was about twice as high in sows which had been crated throughout gestation and farrowing compared to sows which had been kept loose for the same period (Bäckström 1973). It is likely that management practice has improved and that the genetic material is different today compared to more than 20 years ago, when this study was carried out, but recent surveys of the same magnitude are not available.

One of the most common diseases in post-parturient sows is the complex syndrome of lactation failure, known as Mastitis-Metritis-Agalactia (MMA). Surveys in Sweden and USA have shown that the prevalence lies between 7 and 13% of farrowings (Bäckström 1973, Martin and Elmore 1980), but with a high variation between herds. In general, litters of affected sows show greatly reduced production performance and the pre-weaning mortality may be up to twice as high as in clinically unaffected sows (Bäckström 1973). Also, subclinical MMA may be considered a major risk factor for the piglets (Algers

1992). In general, the causes of the syndrome are complex, but factors such as stress, environment and management have been emphasised as important in the aetiology of the disease (Tubbs 1988).

There appears to be a close connection between type of housing system and the occurrence of MMA. Pigs farrowing outdoors on pasture are very rarely affected (Bäckström *et al*. 1984). In an epidemiological study in Sweden, sows crated during pregnancy and farrowing had a significantly higher incidence than sows kept loose (11.2 vs 6.7%) (Bäckström 1973). Danish experiments showed that sows kept tethered during farrowing had significantly higher MMA rates than sows kept loose (Hansen and Vestergaard 1984). It should be remembered that MMA detection may be easier when sows are kept confined, so that comparisons may be biased if crude assessments of MMA are used. However, the consistency between the different studies, where different levels of detail in records of symptoms have been used, makes it likely that there is a real increase in MMA-risk when sows are kept crated.

In addition, crated sows have been found to have higher incidences of movement disorders and leg weakness compared to loose housed sows, although these problems may be mostly attributed to crating during the pregnancy period (Broom *et al*. 1995). This is in accordance with Danish studies were crated pregnant sows were found to have relatively high incidences of lesions on legs and bones and swellings on the legs (Jensen *et al*. 1995). Even if the data were obtained for pregnant sows, it seems plausible to consider these health problems caused by crating as such, and they therefore have some relevance also for the case of crated lactating sows.

Another aspect is that management of the sow, treatment of disease and vaccinations are usually considered easier and less demanding for the caretaker if the sow is crated. It is of course a valid welfare argument, that treatment and care of the sows should be as easy as possible.

5.3.7 Environmental effects on stress physiology in the sow

Since studies of sows in natural environments and in experiments have demonstrated that sows apparently have a strong need to perform nest building activities before farrowing, there would appear to be a risk of stress for the sows if they are inhibited from carrying out this behaviour, as is the case in a crate system.

Lawrence and co-workers examined effects of crating on various stress and parturition related hormones in sows (Lawrence *et al*. 1995, Lawrence *et al*. 1994a). Although parturition in itself triggered an increase in cortisol, the plasma levels were considerably higher in crated sows compared to loose sows. The general hormonal effects were interpreted as demonstrating a stress effect of crating, which might interfere with the birth process. It should, however, be noted that in these studies crating was confounded with absence of straw. Furthermore, the sows were all loose housed during the gestation period, so the contrast between housing environments may also have affected the results.

A similar increase in cortisol of crated sows was observed in a study where the physiology of crated versus loose-housed primiparous sows was followed throughout lactation; however, differences were only detectable in the second day post partum (when observations started) and towards the end of the lactation (day 28 post partum) (Cronin *et al*. 1991). This was interpreted as demonstrating a probable stress effect of crating at the time around parturition, probably caused by the inability of the sow to perform nest building, and a similar later effect, perhaps caused by the inability of the sow to get away from the piglets at a time when the natural behaviour of the sow is to spend time away from the offspring.

Fraser and co-workers have suggested that stress around parturition may interfere with the birth process and early maternal behaviour and physiology in the following ways (Fraser *et al*. 1995): (1) Stress may prolong farrowings and thus increase the probability of stillbirth and other birth trauma; (2) Stress may trigger savaging, i.e. aggressive attacks of sows towards their newborn piglets; (3) Stress may increase the general activity of sows during farrowing (restlessness) leading to higher risks for piglets to be crushed. However, as stated by the authors, there is a lack of experimental evidence for these effects, but they remain plausible explanations of how stress may influence the welfare and reproduction of the sow.

5.3.8 Environmental effects on welfare of sows and piglets during the lactation period

The sow and piglets are exposed to the farrowing environment for varying times after the birth. Most commonly, the pigs are kept in the farrowing pen up to weaning, but other systems exist, where sows and piglets are moved after some time (Phillips and Fraser 1993).

In one experiment, sows kept either loose or confined during gestation were housed either in crates or in a specially developed pair-pen system during lactation. Irrespective of gestation environment, sows in crates directed less behaviour towards their piglets and were less responsive to piglets and their vocalizations compared to loose housed sows, indicating that the maternal responsiveness was decreased by crating (Cronin *et al*. 1996b). In a Danish experiment, sows were offered stimuli and possibilities for nest building before farrowing (access to straw rack and sand floor), and the mother-offspring behaviour was studied throughout lactation and compared to sows kept in similar loose-hose pens without nest building stimuli (Svendsen Herskin 1996). It was observed that the mother-offspring bonding was stronger in sows which had been able to perform nest building and there were positive effects on reduced crushing, increased responsiveness to piglet distress vocalizations, and longer suckling durations.

When sows are kept crated with the piglets throughout lactation, hormonal signs of stress have been detected in sows towards the end of the lactation period (day 28 post partum) (Cronin *et al*. 1991). It is conceivable that the cortisol increased at a time when free-ranging sows tend to spend less time with the piglets and may be designed to attempt to get away from the piglets (Jensen 1988, Jensen and Recén 1989). When sows have been kept in a system where they can leave the piglets through a specially designed gate, they frequently chose to stay away from the piglets for long periods after the third week of lactation (Boe 1993), some sows even earlier than that.

A common alternative to keeping sows and piglets in the farrowing pen is to move them to some kind of group pens, where several sows are kept with their litters (often referred to as "multi-suckling units") (Algers 1991). In the newer versions of these systems, the sows are grouped already before farrowing, give birth in small compartments within the group pen and are therefore never moved during the lactation (Algers 1991, Goetz and Troxler 1995, van Putten and van de Burgwal 1989). The mortality of piglets has sometimes been higher in these systems, but in most other aspects, the welfare of the sows and the piglets have been reported to be better than in systems where the sows are crated (Algers 1991, Goetz and Troxler 1995, van Putten and van de Burgwal 1989).

5.3.9 Conclusions

76. The average piglet mortality in pig breeding is unacceptably high and measures should be encouraged to reduce this mortality without adversely affecting sow welfare.

77. Farrowing crates have both advantages and disadvantages from a welfare point of view. The advantages of farrowing crates over loose housing systems are: reduced piglet mortality caused by crushing; easier management including better farrowing surveillance possibilities; easier health control (including early detection of anomalies) and, in case of disease, easier treatment of the periparturient sow. The disadvantages of the farrowing crate over loose housing systems are: reduced possibilities for the sow to perform nest building behaviour; signs of increased stress before parturition; some studies indicate a decreased risk for MMA in the periparturient sow when kept loose.

78. Farrowing crates restrict the movements of the sow and usually sows are not given straw when in crates. It is not yet elucidated which of these factors, confinement and lack of straw, contribute most to those negative welfare aspects of the farrowing crate which were mentioned in the previous conclusion.

79. The extent to which welfare is reduced by keeping sows in farrowing crates for the whole lactation needs to be further elucidated; such effects have been suggested by certain studies.

80. Recommendation: The further development of farrowing systems in which the sow can be kept loose and carry out normal nest building, without the systems compromising piglet survival, should be strongly encouraged.

5. 4 Weaning and the Weaned Piglet

5.4.1 Introduction

In mammals weaning is a spontaneous event that naturally occurs. Beyond a certain time of lactation, milk supply is usually progressively reduced whilst concurrently the young has become able to find feed on its own. In the feral pig, the suckling phase naturally ends when the piglets are around 3 to 4 months of age. In the domestic pig raised for meat production, economic considerations have led through the years, and especially since the beginning of the seventies in many countries of Europe, to the shortening of the lactation phase. This was part of the change in management practices towards more intensive systems. Annual herd productivity could be markedly increased through a higher number of farrowings per sow per year. Several other practices have been developed with the same objective of a better farmer's income through mortality limitation, improved daily weight gain and feed conversion ratio. A broad spectrum of weaning diets and housing facilities have been designed in order to prepare the young for weaning and to receive the weaned piglet. However, in modern intensive systems, weaning remains a critical issue.

5.4.2 Weaning : a critical period for the piglet

Weaning has been defined as the time of final cessation of nursing and suckling activities (Consilman and Lim 1985). More generally, weaning marks the end of the preferential relationships between the sow and the piglets. The intensity of the changes that occur in the piglet at weaning is strongly dependent on its age at weaning. A clear rupture is induced in early weaning whereas it becomes more progressive as weaning age increases and as, in parallel, the piglet gets more autonomous, especially for feeding. Nutritional changes and related physiological aspects are probably the most important events occurring at weaning in the common situations encountered in practice. At the small intestine level, the morphological structure of the border is greatly altered at weaning. The villi are dramatically shortened whereas the crypt depths are increased within the first 3-4 days postweaning (Kenworthy 1976, Cera *et al.* 1988, Nabuurs *et al.* 1993). After this, the villi take on a new shape. During the immediate postweaning phase, the fluid and electrolyte absorption capacity of the gut may be temporarily reduced (Nabuurs *et al.* 1994) but the adaptive digestive capacity of the piglet is considerable (Aumaître *et al.* 1995, Pierzynowski *et al.* 1993). Besides nutrition *per se*, the rupture of the maternal link for milk supply has consequences on gut local immune status of the piglet and on the gut microflora (Barnett *et al.* 1989, Hampson *et al.* 1985). *E. coli* bacteria can take advantage of the disturbed situation in the biotype to proliferate and produce toxins. Finally, changing of accommodation and mixing usually occur at weaning. The obvious consequence of all these simultaneous physical, nutritional, immunological and emotional changes is that weaning starts a critical phase (Pajor *et al.* 1991). In this context, water intake did not seem related to feed intake during the first 5 days postweaning whilst later it increased in parallel with feed intake (McLeese *et al.* 1992). With respect to welfare, although behavioural deviations occur, the most frequent issues we have to cope with in the field during the postweaning period are health disorders and related production inefficiencies. Health disorders are mainly digestive, diarrhoea being the prevalent clinical sign but mortality can happen and growth can be considerably impaired (Madec and Josse 1983, Svensmark 1989).

5.4.3 Housing and management systems at the weaning stage

Although under natural outdoor conditions weaning in the pig remains a sow's decision (Boe 1991), in modern pig farming the decision commonly belongs to the farmer. In pig production, age at weaning is a key - component of herd management and numerous attempts have been made to adapt housing and husbandry. Data concerning large scale herd monitoring schemes indicate an average age at weaning ranging from 21 to 35 days (Table 5.4.1). In France it stabilized at 27 days on average in 1995 (Dagorn 1996).

Besides these data coming from the field, others can be obtained from experimental stations. Table 5.4.2 shows the age at weaning of the piglets involved in a broad spectrum of experiments since 1990. Most of the values fall into the 21 - 35 days interval and are close to the data coming from the field.

In certain countries, the sow herds are managed according to a batch system in which the herd is divided into 7 subsequent groups of sows farrowing at three-week intervals. In these conditions, weaning occurs every 3 weeks, usually on Thursday, when the piglets are 26 - 28 days old on average. Four to six days later, the sows are presumed to show oestrus and are mated or inseminated again. In case of return into oestrus, the concerned sow falls into the next batch. This type of management allows the farmer to plan the tasks far ahead. Attention can be focused on critical days (days of farrowing, weaning, oestrus detection, insemination). Furthermore, the buildings are made of compartments and rooms that can be totally cleaned between batches. In large herds, this system tends more and more to move towards a weekly weaning system.

In recent years, a strong trend has emerged aiming at an early removal of the piglets from the sow. Weaning can be designated from 7 to 14 days post partum. Initially, the purpose was to obtain cleaner piglets with respect to pathogenic micro-organisms, since the sow is supposed to be the main source of the latter (Alexander 1980). In the nineties, the technique grew up in the United States. Since early weaning was practised under the cover of antibiotics and vaccines, it took the name of Medicated Early Weaning (MEW). Variant procedures were adapted for commercial purposes and other names were seen: Modified MEW, Isowean (Harris 1990, Connor 1990). It was rapidly noticed that a most important issue was to keep these piglets in adequate isolated facilities to maintain them safe and clean. Drug usage could be limited when adequate palatable diets were designed (Tokach *et al.* 1994, Nessmith *et al.* 1996). Thus, other names were used like Segregated Early Weaning (SEW), multiple-site production or 'off-site' early weaning (Wiseman *et al.* 1992, Clark *et al.* 1994). SEW is not yet widespread in Europe but, beyond the actual primary sanitary goal of early weaning, it may be of interest in the future. Because of the unceasing progress of genetics towards hyperprolificacy, large litters are expected. It is doubtful that such large litters could remain safe and that the sows could physically and physiologically support them during a long lactation. An emphasis is already given to split weaning (Pluske and Williams 1996). The consequences for the sow of weaning the piglets at different ages were studied several years ago (Varley and Cole 1978 , Walker *et al.* 1979). Early weaning (7-10 days) was shown to increase weaning-to-oestrus interval and embryonic losses in the next pregnancy. Studies involving recordings on a large number of farms have shown that litter size at birth is consistently reduced with a decrease of lactation length, especially when shorter than 20 days (Dagorn *et al.* 1996). On the other hand, weaning in the range 20-28 days was found to be the most profitable in terms of piglets weaned per sow per year on routine basis.

The design of the weaning accommodation varies greatly between countries and farms. At the time this review was written, no exhaustive nor precise data were available at the country scale. Only major trends could be obtained for a limited number of countries (Table 5.4.3). The weaned pigs classically receive a dry diet, either pelleted or not. The highly palatable and digestible diet given to the suckling piglet (creep feed) can be continued during the first days postweaning (phase I diet), and then the phase II is given. In case of SEW, more complex feeding programmes have been proposed (Nessmith *et al.* 1996). Finally, since the weaning period is not without danger regarding health, medication is rather usual and is either incorporated in the weaning diet or is added by hand to the feed. It can also be administered through the water. In all cases, there is the need for a prescription from a veterinary surgeon.

5.4.4 Production systems and welfare of the weaned piglet

Behavioural aspects of welfare have been assessed by raising domestic pigs in semi-natural enclosures. Weaning occurred around 3 months post-partum (Newberry and Wood-Gush 1985, Jensen and Stangel 1992). It was found that weaning takes place gradually, without any sudden and drastic changes in behaviour or social dynamics. Littermates kept stronger social inter-relationships than they did with any other pigs. Economic constraints of contemporary pig farming have imposed the need to shorten lactation to the levels mentioned above (Tables 5.4.1 and 5.4.2) and thereby clearly to increase the abruptness of the rupture between the sow and the litter, increasing at the same time the risks of welfare problems in the piglets. Therefore, as a result of this, a number of investigations have been carried out with the goal of reducing these risks. Different components of zootechnics are concerned.

The first is probably the general management, with special emphasis on the age at weaning. Higher plasma cortisol concentrations were found in pigs weaned at 3 weeks compared to those weaned at 8 weeks (Worsaae and Smidt 1980). An early weaning age was found to decrease cellular immune reactivity and these changes were suspected to affect disease susceptibility in young pigs (Blecha *et al.* 1983). A reduced potential for interleukin-2 production has also been reported following weaning at 3 weeks of age and individual variation seemed to increase with time after weaning (Bailey *et al.* 1992). Metz and Gonyou (1990) reported a higher neutrophil/lymphocyte ratio in pigs weaned at 4 weeks than in pigs weaned at 2 weeks. The behaviour of postweaning piglets weaned at 4 or at 6 weeks in a similar environment did not differ markedly. A higher frequency of massaging penmates for piglets weaned at 4 weeks was the only difference (Boe 1993). Three days after weaning, morphological characteristics of jejunal villi were similar in piglets weaned at 21 days and in those weaned at 35 days (Cera *et al.* 1988). However; it must be noted that none of the piglets ingested creep feed in this trial. This point is of major importance since, in most experiments and field surveys, modifying weaning age induces automatically several other changes that may act as confounding factors. Particular attention must be paid to the liveweight of the piglet at weaning, which may be a further confounding factor. Depending on the trials, average liveweights can vary from less than 7 to more than 8 kg for a standard age of 28 days at weaning. Liveweight differences may explain some of the discrepancies observed in the results of the trials on weaning. Weight at weaning is the result of a complex biological equation, with some parameters determined early in life and that may strongly interfere with behaviour, growth and health, hence welfare, during the postweaning phase.

Through cannulation at the terminal ileum, the effect of weaning age (21 days vs 28 days) was investigated on intestinal microflora population. pH and dry matter were of greater magnitude and persisted for longer periods in pigs weaned at 21 days, attesting a higher susceptibility of the younger piglets to weaning challenge. This has been unfortunately experienced in the past. The first attempts to wean piglets at 14 days or earlier led to considerable losses (10 - 15%) most of which were due to diarrhoea despite medication (Alexander *et al.* 1980, Meszaros *et al.* 1985). Segregated early weaning is a combination of many technologies: early separation of the piglet from the dam, highly palatable and digestible diets, special nursery facilities with adequate climate, all-in all-out hygiene policy in each room. In the US, the whole system, when handled properly, now gives substantial improvement in the health level and productivity in the concerned herds (Clark *et al.* 1994, Dritz *et al.* 1996). We must, however, agree that the farmers must realize that new sophisticated technologies bring about, in turn, risks of new problems.

In conventional production systems, age at weaning strongly influences creep feed intake. The latter remains rather low until the fourth week post partum, during which a considerable increase is observed (Pajor *et al.* 1991, Boe 1991, Appleby *et al.* 1991). Creep feed consumption is not without importance with respect to the structure and function of the gut mucosa. The villi were less affected by the weaning process when the piglets had a good creep feed intake before weaning at 30 - 32 days (Nabuurs *et al.* 1993). Probably in connection with this, it was also shown that creep feeding activity prior to weaning was of benefit for dry feed intake in the early postweaning phase (Fraser *et al.* 1994). On farms, the risk of postweaning digestive problems was reduced when age at weaning reached a certain level (Madec and Josse 1983, Svenmark 1989). A recent epidemiological survey in France (Madec *et al.* 1997) corroborates this conclusion, and it was shown that age at weaning *per se* from 3 weeks onwards, could not be the cause of the syndrome. The problem needs to be analysed in term of risk profiles. Postweaning digestive disorders were to be feared when several elements in husbandry were simultaneously failing. Those related to housing, hygiene and other management conditions from weaning onwards were found to be critical. In Australia, the inability of pig sheds to provide an ideal environment for the weaners was also reported (Buddle *et al.* 1994).

A lot of investigations have been carried out in experimental facilities to investigate the role of different factors, taken in isolation, that might influence the welfare of the weaned pig. The behavioural component of welfare has been particularly studied. The benefits of mixing the litters as early as the suckling phase was assessed (Goetz and Troxler 1995, Braun 1995). A specific-stress-free housing system in which the piglets were not mixed nor transported was tested and found to result in better growth rates than controls (Ekkel *et al.* 1996). A family pen housing system where the piglets were weaned when at least 7 weeks was adapted in a commercial farm in Switzerland (Weschler 1996). In Germany the behaviour and performance of weaned piglets were compared on deep compost bedding and in flat-decks, with an advantage to the former (Bunger and Kallweit 1993). Other studies were undertaken, along the same lines, trying to reduce the intensity of fighting when the piglets were mixed at weaning. The presence of straw did not modify the frequency of aggressive interactions but the latter could be reduced by setting up a barrier in the pens (Waran and Broom 1993). Partitioning the pens, however, is not conclusive in every case (Olesen *et al.* 1995). The effects of individual *vs* group penning were assessed without significant differences in performance and stress in piglets weaned at 28 days (Bustamante *et al.* 1996). In a field survey, the farms where no postweaning digestive disorders were seen kept their weaning pigs in smaller groups on average than did affected farms (Madec *et al.* 1997). Increasing space allowance and enriching the environment were found to reduce belly nosing, tail chewing and aggressive behaviour in the young pig (Wood-Gush and Beilharz 1983, Grandin 1989, Schaeffer *et al.* 1990). From an experimental attempt to identify which factor, enrichment or space allowance, had more influence on pig behaviour, it was concluded that enrichment of the environment, was not totally effective in reducing the frequency of these activities (Petersen *et al.* 1995).

Other investigations were devoted to the comparison of different types of accommodation and again the targets were mainly behavioural criteria. Pens with fully perforated floors without straw were compared to pens with part-solid floors with or without straw (McKinnon *et al.* 1989). The observations were made in two different seasons and external climate interfered with internal climate. Peaks of activity were observed in all treatments but, overall, a great part of the behavioural differences recorded were attributable to climate interaction. A higher prevalence of oral/nasal behaviour directed at penmates and pen fittings was however reported on fully perforated floors. When straw was used, it gave an alternative occupation to the piglets. A comparable approach was used in Denmark (Dybkjaer 1992) in an attempt to identify behavioural indicators of 'stress' in the general sense of the word (Fraser *et al.* 1975). Two systems were compared. The first, named 'L', in which the piglets remained with littermates, had 8 piglets per pen with 0. 30 m^2 per pig. Straw was provided daily on a wooden plate. The second system, named 'H', was a totally slatted metal floor without straw. These pens housed 16 piglets coming from 2 litters, mixed at weaning. Floor surface per pig was half of that in 'L' (0.15 m^2/pig). The significant differences in behaviour patterns between the two treatments at 2 and 4 weeks after weaning concerned belly - nosing, manipulating ears, tail or other parts, chewing a chain and sitting passive, criteria which were all higher in treatment 'H'. In this treatment, it was suggested that an important part of exploratory behaviour was directed to penmates and to the fittings instead of to straw. However no physical detrimental consequence was reported, although daily weight gain tended to be lower. In another trial conducted in UK, a standard flat deck was compared to a similar flat deck but enriched with recreational objects (chain, tyre). Straw bedded pens were also involved in the study as a third system (English *et al.* 1994). A very low prevalence of belly nosing, of ear or tail chewing and of interacting with the pen structures was observed in any treatment. The playthings added did not seen to be very attractive. There was evidence of adventitious bursitis of the hock in the piglets kept in the flat deck systems but growth rates were higher in these systems. Overall, the authors remained cautious about welfare differences between the systems.

There is no doubt that environment is of paramount importance to achieve an acceptable level of welfare in the weaned pig. In addition to the type of accommodation, the influence of climate has been investigated. Questions may rapidly arise when interpreting the results of these studies, since strong interactions may exist between the climate challenge and the type of accommodation. Cold air draughts had large effects on behaviour (Scheepens *et al.* 1991). Excessive aggression was detected and claimed to potentially induce detrimental consequences on health and performance. On the other hand there is evidence that cold stress *per se* can also affect health in the weaning pig (le Dividich and Herpin 1982)

The immune system may be involved in the process (Kelley 1982). In the absence of other risk factors, piglets kept at thermoneutrality were thought to be unlikely to suffer postweaning diarrhoea, even in the presence of an enteropathogenic strain of *E. coli* (Wathes *et al.* 1989). A high air velocity (0.4 m/s) reduced average daily gain of weaned pigs, although temperature was maintained at around 24°C (Riskowski and Bundy 1990). The huddling behaviour of the pigs was also strongly modified but the blood parameters (complete blood count) taken for assessing stress did not react (Riskowski *et al.* 1990).

5.4.5 Conclusions

81. So-called segregated early weaning may have welfare advantages by decreasing the risks of infection of the piglets, but may cause reproductive problems in the sows. The welfare advantages may, to an unknown extent, be attributable to the practice of moving the piglets to another rearing site. However, other welfare aspects of the process, for example the behavioural and physiological responses of both sows and piglets, have not been studied.

82. Weaning is associated with increased risks of welfare problems, identifiable as abnormal behaviour, increased disease incidence, increased mortality and impairment of growth. These problems become more severe the younger the piglets are at weaning, but can be met by appropriate housing and husbandry routines for the newly weaned piglet.

83. Recommendation: The average weaning age should not be less than 28 days. However, for practical reasons associated with the health benefits of all-in all-out management, piglets may be weaned up to 7 days earlier. Individual piglets may occasionally be weaned earlier for medical reasons, for example if the sow ceases to lactate, becomes diseased or dies.

84. Recommendation: So-called segregated early weaning (weaning the piglets at 10-14 days and separating them from the maternal environment) should be allowed only if it is demonstrated that any welfare advantages to sows and piglets outweigh the disadvantages. In this respect, any advantage of multi-site rearing or of moving to new sites should be clearly distinguished from the effects of early weaning. Welfare assessment should take account of signs of poor welfare, such as mortality, diarrhoea, growth rate and behavioural indicators such as belly-nosing by piglets that maternal deprivation is causing problems to the piglets.

Table 5.4.1 - Age at weaning obtained from large scale recording schemes

Authors (year)	**Country**	**Age at Weaning (days)**	
		mean	**SD**
- Anonymous (1996) *Annual report 1995.* National Committee for pig breeding, health and production	Denmark	29	
- Anonymous (1996) *Resultados GTEP Periods* 02/07/95 - 30/06/96 IRTA - Porc	Spain	25	
- Anonymous (1996) *Résultats nationaux* Programme GTTT 01/07/95 - 30/06/96	France	27	1. 7
PIC UK (1996)	United-Kingdom	26.1	

Table 5.4.2 - Weaning age of piglets involved in experimental trials

Authors	Age at weaning (days)	Purpose of the Trial
• Kelly *et al* 1990 (UK)	14-21	creep feed intake and post weaning diarrhoea
• Funderburke and Seerley 1990 (USA)	28	effect of different changings
• Riskowski and Bundy 1990 (USA)	21	climate and performance
• Appleby *et al* 1991 (UK)	26 - 29	creep feed intake and growth
• Dunsford *et al* 1991 (USA)	21	diet and small intestine changes
• Li *et al* 1991 (USA)	21	diet composition and immunology
• Pajor *et al* 1991 (CAN)	28	creep feed consumption
• Scheepens *et al* 1991 (NL)	35	climate and behaviour
• Howers *et al* 1992 (NL)	28	housing and behaviour
• Dybkjaer 1992 (DK)	27	behaviour
• Waran and Broom 1993 (UK)	24	housing and behaviour
• Boe 1993 (Norway)	28 and 42	age at weaning and behaviour
• Nabuurs *et al* 1993 (NL)	30 - 32	digestive tract morphology
• Risley *et al* 1993 (USA)	21	diet composition and health
• Meunier - Salaün *et al* 1994 (FR)	21	diet composition and behaviour
• Fraser *et al* 1994 (CAN)	28	feeding at weaning
• Makkink *et al* 1994 (NL)	28	diet composition, growth and nutrition
• Dove 1995 (USA)	26	diet composition and nutrient utilization
• Tokach *et al* 1995 (USA)	21	diet composition and performance
• Petersen *et al* 1995 (DK)	35	environmental stimulation and behaviour
• Olesen *et al* 1995 (DK)	28.5	housing and behaviour
• Rantzer *et al* 1995 (Sw)	35	housing and behaviour
• Dritz *et al* 1996 (USA)	7 - 10	growth and microflora in early weaning
• Mathew *et al* 1996 (USA)	21 - 28	postweaning microflora
• Christison 1996 (CAN)	27	light and behaviour
Pluske and Williams 1996 (Australia)	22-29	split weaning and growth

Table 5.4.3 - Main types of weaning accommodation for piglets in some EU countries

Country	Major type of floor	Bedding	Type of ventilation
Denmark	slatted floor	no	fans
France	slatted floor	no	fans
Germany	total / partial slatted	no / yes	natural / fans
Italy	slatted floor	no	fans
The Netherlands	slatted floor	no	natural / fans
Sweden	concrete	yes	natural / fans
Spain	slatted floor	no	fans
United Kingdom	concrete / total / partial slatted	yes	natural / fans
Greece	slatted floor	no	fans

5.5 Growth-finishing pigs

The most prevalent housing systems for growing and finishing pigs between 30 and 110 kg are pens with slatted or partially-slatted floors in insulated and ventilated buildings. Aspects of straw or other bedding materials in systems with solid flooring are discussed in Chapter 4.1. Fattening pigs usually have *ad libitum* access to automatic feeders (up to 4 pigs per feeder space) or single wet feeders (12 to 15 pigs per wet feeder). Growing/finishing pigs may also be fed simultaneously from a trough, either with dry feed or with liquid feed that has been previously mixed and pumped to the animals' feeding trough.

5.5.1 Feeding

Pigs prefer to eat simultaneously, spending a substantial period of the day in foraging and feeding when observed under semi-natural conditions (Hsia and Wood-Gush, 1983, Stolba and Wood-Gush, 1989). Limited resources (i.e. feed) can increase aggression, allowing a dominant animal to have access to the resource (Csermely and Wood-Gush, 1986). Simultaneous feeding of fattening pigs would therefore prevent competition during feeding, although the problem of competitive encounters due to limited feeder space is usually less pronounced in fattening pigs that have *ad libitum* access to feed. Performance of fattening pigs that are fed through a single wet feeder is not negatively influenced when they are kept in groups of up to 12-15 pigs/feeder. Nielsen *et al*. (1995) used computerized feed intake recording to evaluate behaviour and performance of growing pigs in groups of 5, 10, 15, and 20 with one single feeder space per pen. There were no differences between groups in production variables and a change in feeding pattern in the largest groups appeared to represent an adaptation to the constraints placed on their feeding behaviour. Also, no significant effect of group size was found on mean number of attempts to displace other pigs from the feeder. Problems with competitive aggression are more acute in group-housed gestating sows under a restrictive feeding regimen without access to individual feeders (see Chapter 5.2).

5.5.2 Social structure, space and group size

Pigs form stable hierarchies when kept permanently together in relatively small groups of approximately 8 to 20 animals. McGlone and Newby (1994) evaluated group sizes of 10, 20 and 40 finishing pigs that were held at 0.8 m^2/pig and found increased injuries and/or deaths in group sizes of 40 pigs per pen. Finishing pigs penned in groups of 16 were observed to behave more socially than pigs in groups of 48 (at the same stocking density), which directed their behaviour to a greater extent towards housing equipment (Pedersen, 1990). Mixing unfamiliar pigs (i.e. between the growing and finishing phase) causes stress, in that they have to compete to establish a new hierarchy, during which period they gain less weight and are less efficient in utilizing feed (Douglas *et al*. 1994). Removal of individual pigs, one at a time, from different places in the social order neither altered the basic social hierarchy nor the amount of aggression within the remainder of the group (Ewbank and Meese (1971). Long term effects of mixing pigs on health and productivity are still unclear, although recent studies suggest that pigs remaining on one site and in stable groups throughout the whole production cycle are superior in health parameters and productivity (Ekkel *et al*. 1996).

Space requirements depend on the weight and the number of pigs kept in the group, and crowding stress can occur when pigs are kept below their individual space requirement (as discussed in detail in Chapter 4.4). Severe space restriction in growing-finishing pigs kept at 0.34 m^2/pig between 25 and 100 kg (in groups of eight pigs), resulted in greater feeding time and lower social activity. Sternum resting was more frequent than resting on the side when body weight reached 60 to 70 kg (Meunier-Salaun *et al*. 1987). The provision of hides for the head and the shoulders, or partitions within a pen of grower pigs, may reduce the incidence of aggression-induced lesions (McGlone and Curtis, 1985). The stimulatory effect of straw or other bedding materials is discussed elsewhere (see Chapter 4.1).

5.5.3 Health, hygiene and productivity

Productivity, behaviour and injury were compared in four housing treatments for pigs within one building: deep-straw, Straw-Flow[R], bare-concrete and slats (Lyons *et al*. 1995). It was concluded that pigs (27 to 90 kg) in the straw housing treatments had lower injury scores and increased growth rates due to increased feed intake. Daily gain of finishing pigs on partially slatted floors was greater when provided with whole straw (Mortensen, 1986). Also, whole straw had a positive impact on keeping pens clean and tended to reduce disease and tail biting in pigs. Jackisch *et al*. (1996) examined the behaviour of fattening pigs in six husbandry systems within the same housing complex but differing in space allocation and straw provision (deep litter, deep litter with bio-activator, 2 types of sloped floor, slatted floor and partially-slatted floor). Pigs in the fully slatted pens developed tail and ear biting, leading to a decreased daily weight gain. Pigs in pens with straw defined their resting and elimination areas in the pen more clearly than those in the fully-slatted system, which can be explained by the straw provision and extra space offered in the bedded systems. Guy *et al*. (1994) compared two genotypes of finishing pig housed in outdoor paddocks, straw yards and fully-slatted pens. They concluded that outdoor paddocks and straw yards may provide an excellent environment for the growing-finishing pig with increased scope for rooting, chewing and locomotion, and give lower levels of internal and external body damage. With small differences between the given ‘indoor’ and ‘outdoor’ genotypes, and few interactions, there appeared to be little or no advantage for pig welfare in specifying ‘outdoor’ genotypes for less-intensive finishing systems.

5.5.4 Conclusions

85. Behaviour, health and productivity of growing and finishing pigs are greatly influenced by the specific design of housing equipment, climatic factors and stockmanship.

86. Tail-biting, abnormal levels of aggression and other behavioural disturbances are more likely among fattening pigs when kept in barren environments.

87. Recommendation: Housing systems for growing and finishing pigs should facilitate separation of functional areas (feeding, resting and dunging area), or prevent direct contact with faeces in the

resting area. They should account for the needs of pigs to investigate and manipulate materials and minimize competition.

88. Recommendation: Pigs that develop destructive behaviours should be removed from the group. Housing conditions in which a high prevalence of destructive behaviour occur should be adequately modified which may include one or a combination of the following measures: adequate light and climate, a sufficient and well balanced diet, cleanness of flooring and equipment, sufficient space, and features providing for occupational activities (bedding material, chains, etc.).

CHAPTER 6 SOCIO-ECONOMICS ASPECTS

6.1 Introduction

This chapter starts with a description of the pig industry in the European Union (EU). An overview is given of the number of pigs in the world and in the different countries of the EU. Also, information is given about the self-sufficiency rate and the total pigmeat consumption and production in the EU.

The major part of the chapter is focused on economic calculations for various welfare improving measures. The impact of the measures on the cost price of the meat and on the farmer's income are shown. These calculations were carried out with a computer simulation model developed by den Ouden (1996)[1], and represent the commercial pig industry.

In the final part of the chapter the (possible) influence of the increase in the price of pigmeat on the behaviour of the consumer is discussed. The so-called price elasticity is briefly explained. Two situations are considered: one without import of pigmeat from outside the EU and one when (cheaper) pigmeat from elsewhere is able to enter the EU market. The major conclusions are also presented.

6.2 Overview of the pig industry

6.2.1. Number of pigs and farms

In 1994 there were 878 million pigs world-wide (Eurostat, 1996), of which 19.8% were in the EU (see Figure 6.1). Asia was the leading area, with 56.8% of all the pigs.

Figure 6.1 Percentage of pigs world-wide in 1994 (Eurostat, 1996).

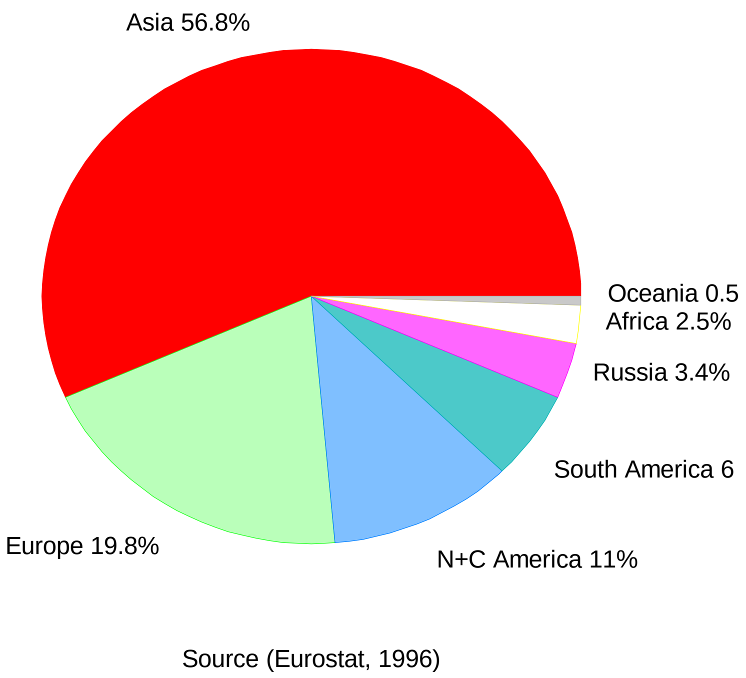
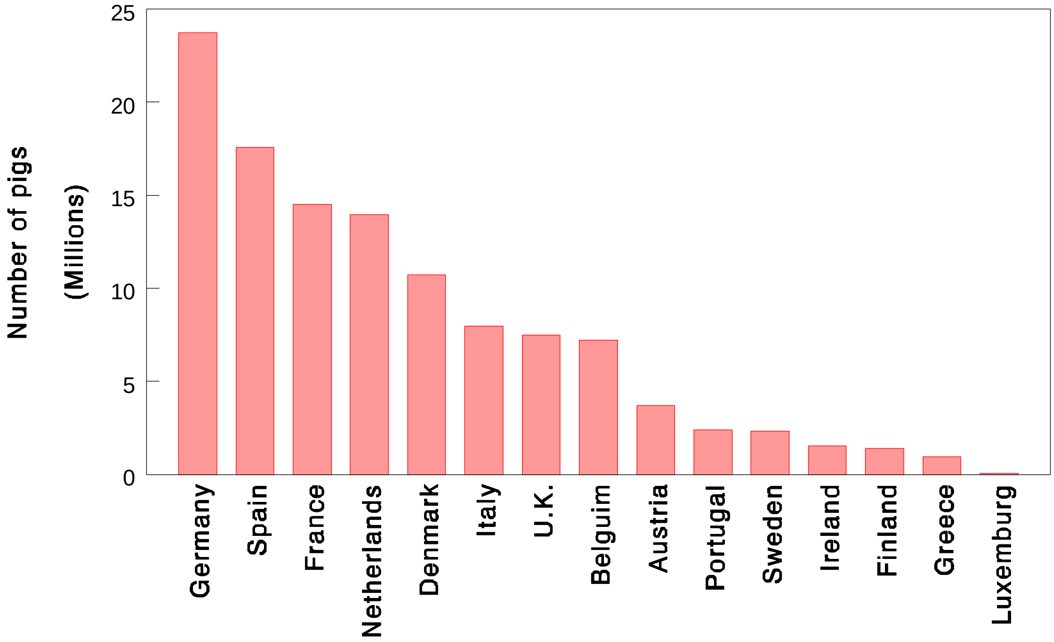


Figure 6.2 Pig population per country in the EU in December 1995 (Eurostat, 1996)

[1] The model is owned by Nutreco and made available for this research without charge.



The total number of pigs in the EU in 1995 was 115.6 million. The number of pigs per country is given in Figure 6.2. Germany was the leading country (24 million), followed by Spain (17.5 million), France (14.5 million), The Netherlands (14 million) and Denmark (11 million). The number of pigs increased until the year 1993 to 119.3 million and has decreased since then (Eurostat, 1996).

The herd size per pig farm in the EU ranges from 1 to more than 2000 pigs. There are big differences between countries with respect to herd size (Table 6.1). Countries such as Italy, Greece, Spain and Portugal have high numbers of very small farms; respectively 91%, 87%, 85%, and 85% of the total number of farms in these countries have less than 10 pigs. In these countries, however, the greatest part of the pig population is still housed in farms with more than 1000 pigs. For example in Italy 5.745 million of the 8.348 million pigs are housed in farms with more than 1000 pigs, a percentage of 69% (Eurostat, 1996). The proportion of small farms in countries such as The Netherlands, Denmark, Belgium and Sweden is much lower; respectively 4%, 7%, 11% and 16% of the total farms in these countries have less than 10 pigs (Eurostat, 1996).

Table 6.1 Structure of pig farms in Europe in 1993 (Eurostat, 1996).

		Number of pigs per farm						
	pig farms (*1000)	1-9	10-49	50-99	100-199	200-399	400-999	>1000
		percentage of pig farms in each category						
EU-15	**1569.1**	**73**	**11**	**4**	**4**	**3**	**3**	**2**
Spain	440.0	85	7	3	1	1	2	1
Germany	293.8	51	22	8	7	6	5	1
Italy	273.4	91	6	1	0.4	0.4	0.5	0.5
Portugal	149.8	85	11	1	1	0.3	0.2	0.1
Austria	127.0	72	14	5	5	4	1	-
France	120.2	77	6	2	3	3	6	3
Greece	51.1	87	9	1	1	1	1	0.4
Denmark	26.9	7	20	13	14	15	19	12
Netherlands	26.9	4	7	10	17	20	25	17
UK	17.5	32	23	6	7	8	11	13
Belgium	15.2	11	13	10	14	16	23	13
Sweden	13.0	16	26	16	16	16	10	-
Finland	11.0	27	9	18	27	19	-	-
Ireland	2.8	46	25	4	4	4	7	10
Luxembourg	0.7	41	29	10	10	10	-	-

6.2.2 Production, consumption and self-sufficiency of pigmeat

The self-sufficiency rate is defined as the ratio between the domestic production and the domestic consumption (multiplied by 100). Countries with a self-sufficiency rate of more than 100% export to other countries. Countries with a self-sufficiency rate of less than 100% import pigmeat from other countries. The self-sufficiency rate and human consumption of pigmeat differ among countries (Table 6.2). As there is no information available from Finland, the total numbers in Table 6.2 refer to EU-12 instead of EU-15. Denmark is the country with the highest self-sufficiency rate and therefore the leading country in the export of pigmeat, followed by The Netherlands and Belgium/Luxembourg. There are big differences in the human consumption of pigmeat per head among countries. In Denmark the consumption averages 63.3 kg per person, while in Greece this is only 22.7 kg only.

Table 6.2 Self-sufficiency rate and human consumption of pigmeat per country in the EU in 1994 (Eurostat, 1996).

Country	Self-sufficiency rate	Consumption (kg pigmeat/head/year)	Country	Self-sufficiency rate	Consumption (kg pigmeat/head/year)
EU-12	**106.2**	**41.1**	France	101.3	36.2
Denmark	467.8	63.3	Portugal	88.0	34.6
NL	283.0	44.4	Germany	76.9	55.6
B&Lux	193.0	48.9	UK	75.5	24.0
Ireland	160.5	36.2	Italy	68.2	33.2
Austria	105.4	55.9	Greece	60.2	22.7
Spain	103.6	54.2	Finland	-	-
Sweden	103.0	34.0			

Table 6.3 shows an increasing production and consumption of pigmeat in the EU in the years from 1991 to 1993. In these years, beef showed a slight decrease and poultry meat a slight increase. The increase in total consumption of meat (kg/head) from 93.5 to 95.7 in the EU was, in the greatest part caused by the increase in the consumption of pigmeat.

Table 6.3 Production and consumption of (pig)meat in the EU (CAP, 1995).

Year	Production of pig-meat (1000 ton)	Consumption of pigmeat (kg/head)	Total consumption of meat (kg/head)
1991	14339	39.8	93.5
1992	14387	40.2	93.6
1993	15277	42.0	95.7

There is extensive trade in pigmeat among countries of the EU, as summarised in Appendix 6.1. The Netherlands is shown to be the leading country in exporting pigmeat within the EU. In total, 776.38 million kg of pigmeat from the Netherlands is exported to countries of the EU. Denmark and Belgium/Luxembourg follow with 565.86 million kg and 515.20 million kg of pigmeat respectively.

6.2.3 Employment in the pig sector

Almost 6% of the civilian employment in the EU is in agriculture, forestry and fisheries. The number of people working in the pig industry in the EU is not precisely known (Eurostat, 1996). Available estimates are summarised in Table 6.4.

Table 6.4 Estimates of employment in the pig sector.

Country	On pig farms	Related industry	Total	Pigs (million)
Netherlands[1]	16050	36560	52610	14
United Kingdom[2]	11400	11500	22900	7.5
Brittany (France)[3]	10000	13000	23000	7.6*
Denmark[4]	25000	28000	53000	11
Italy[5]	26000	26200	52200	8

* Number of pigs in Brittany only (Nagel, 1995)

Sources of the estimations:

[1]Product Boards for Livestock, Meat and Eggs
[2]British Pig Association
[3]Institute Technique du Porc
[4]Danske Slagterier
[6]Industrial and Breeder Organisations

In these 5 countries, on average, each 257 pigs provide 1 job (data do not allow determination whether these jobs are all on a full-time basis). With a total of 174 million pigs in the EU, this would lead to work for 174 million / 257=677,000 jobs in the entire pig sector in the EU.

6.3 Economic calculations of welfare improving measures

6.3.1 Introduction

In this paragraph economic calculations are presented of measures that are assumed to improve animal welfare. The economic calculations include and compare newly-built housing systems, and hence do not focus on all types of possible renovations of existing buildings. The calculations were carried out with a computer simulation model, developed by Den Ouden (1996). The model includes very detailed specifications on the various type of housing, investments, labour input, technical performances and prices. The specifications were based on literature, where possible, combined with experts' opinion. Single chapters of the thesis were published in the international scientific literature.

In using the model for the underlying research, Dutch farm and price conditions for commercial pig farms were included as the basic situation. Information on the level of the major input variables of the model for other countries, however, has also been gathered and presented, which can help to provide insight into the representativeness of the modelling outcome for other farm and price conditions. The economic comparison of the various measures/systems was carried out assuming equal performance with respect to factors such as weaned piglets per sow, growth rate of fattening pigs, feed conversion, mortality rate and health costs. This is because literature and expert opinion most often differ on the precise relationship between welfare improving measures/systems and the level of these performance parameters. Therefore, the economic impact of differences in the most important technical performances parameters was calculated separately and is given in Appendix 6.2. This makes it possible (and flexible) to include the economic impact of such changes in the calculated outcome of welfare improving measures/systems where desired, and according to each individual belief/opinion with respect to the extent of such changes. The number of sows and fattening pigs per farm were chosen to represent a commercial family farm (i.e. about one full-time equivalent of labour).

6.3.2 Economic description of the basic situation

The basic sow farm has 165 sows. The pregnant and non-pregnant sows are kept in fully slatted crates, with 1.4 m^2 of space per sow, and the farrowing sows are kept in farrowing crates with 3.75 m^2 per sow. The average number of liveborn piglets per sow per cycle is 11 and the average number of weaned piglets per sow per year is 21.50. Piglets are weaned at an age of 28 days and sold to the fattening farm at an age of 70 days and a weight of 25 kg. The piglet mortality before weaning is 13.2%. The annual replacement rate for the sows is 40%. There is some outdoor concrete available to stimulate sows into oestrus. On average per sow 14.5 hours of labour are needed per year. The sows do not receive straw.

The basic fattening farm has 2008 places for fattening pigs. The fattening pigs are housed on partly-slatted floors in compartments of 80 fattening pigs (8*10). Total space per fattening pig is 0.70 m^2 with 0.17 m^2 solid concrete floor. The mortality rate of the fattening pigs is 2.4% and, with an average of 2.91 cycles per year, the number of fattening pigs sold per farm per year is 6077. The fattened pigs leave the farm in 2 batches: the first group includes the 20% fastest growing pigs and the second group the remaining 80%. Live weight at slaughter is 113 kg and carcass weight is 88 kg. The average growth per day is 0.737 kg with a feed conversion (kg feed per kg growth) of 2.82. Per fattening pig 0.39 hours of labour are needed. The fattening pigs do not receive silage nor straw.

In Appendix 6.3 more technical and economic information about the basic sow farm and the basic fattening farm is given. In Appendix 6.4 information can be found about feed prices, wages for labour, straw prices and general aspects for the Dutch situation, as well as for those other (pig) countries that provided data. Labour income is calculated as the net return to labour and management per year, which equals total returns minus costs (excl. costs for labour). The remaining costs are the administration costs, insurance, taxes, manure costs, heating, water, electricity and straw.

6.3.3 Economic calculations for the farrowing farm

From individual housing to group housing for dry sows

Changing the housing system from individual housing to group housing may affect a lot of factors, such as the feeding system, water supply, requirements on the management skills, technical parameters such as growth per day, number of open days per sow, culling rates etc. There are different types of group housing. The group housing that was chosen to be taken into account in the economic calculations is the Electronic Sow Feeding system. The group is a stable group with, on average, 25 sows. In Table 6.5, differences in investment costs are presented. Effects of changes in, for example, technical parameters and management have not been taken into account due to lack of information and/or disagreement in literature and expert opinion. The single economic impact of some technical parameters can be found in Appendix 6.2 and could be added to the outcome in Table 6.5, where considered appropriate.

Table 6.5 Economic impact on investment costs when changing the housing system from individual housing to group housing (ecus).

	Investment building/ sow	Housing cost/sow/year	Total cost/ sold piglet	Labour income	% change in labour income	Change of cost price per kg fattening pig
Individual •	2617	353.56	56.71	14863	**100%**	**1.580**
Group housing	2564	346	56.37	16062	**+8%**	**-0.004**

- basic situation

Extra investment is needed for the Electronic Feeding System within group housing, but Table 6.5 shows that the total investment per sow decreases for the group housing system under consideration. The main reason for this decrease is that the expensive crates are not needed anymore. Some group housing systems such as Free Access Stalls or Biofix/Trickle feeding do use crates, and for these systems the investment per sow is higher than in the basic (i.e. individual housing) situation. For these group housing systems, the costs of investment would increase by 28% and 4% respectively, compared to the basic situation, making group housing the more expensive option (Backus *et al.*, 1996). It is also important to consider that small changes in technical parameters - as calculated in Appendix 6.2 - can easily outweigh the positive change in labour income presented in Table 6.5. An increase in the annual culling rate of sows of 3 to 4%, for instance, would result in a decrease in income of 6 to 10%. A decrease of 0.1 piglet per cycle results in an 8 % decrease in labour income.

Within group housing, the amount of space per sow can be increased. The economic impact of increasing the space from 2 m^2 to 2.5 and 3 m^2 within the Electronic Sow Feeding system is shown in Table 6.6. An increase in space of 0.5 m^2 per sow increases the cost price per kg by 0.002 ecu and decreases labour income of the farmer by 4%.

Table 6.6 Economic impact of increasing the space per sow in group housing (ecus).

space (m^2)	Investment Building/ Sow	Housing cost/sow/ year	Total cost /sold piglet	Labour income	% change in labour income	Change of cost price per kg fattening pig
2 •	2564	346.44	56.37	16062	**100%**	**1.577**
2.5	2593	350.34	56.55	15406	**-4%**	**+0.002**
3.0	2622	354.25	56.74	14749	**-8%**	**+0.004**

• group housing

Providing straw within group housing results in higher costs for labour and causes higher remaining costs. The increase in labour is related to providing straw to the sows and the hours needed to remove the dirty straw. The increase of the remaining costs is a result of the costs for the straw as such. Because of more labour needed per sow, the number of total sows one person can handle decreases. Table 6.7 shows the effect of providing straw for group housed sows on the change in labour income and cost price.

Table 6.7 Economic impact of providing straw to group housed sows (ecus).

Straw kg /sow/day	Number of sows	Labour cost/ sow	Remaining cost /sow	Total cost /sold piglet	Labour income	% change in labour income	Change of cost price per kg fattening pig
0 •	165	243.98	117.36	56.37	16062	**100%**	**1.577**
0.1	163	246.39	120.46	56.63	15359	**-4%**	**+0.003**
0.2	163	246.39	123.47	56.78	14858	**-8%**	**+0.005**
0.3	163	246.39	126.49	56.92	14358	**-11%**	**+0.006**

• group housing

The economic impact of providing straw is considerable and can exceed the costs of increasing space within group housing. The calculations were done with the assumption that the additional work to be done is carried out manually. It may become possible in the future that providing straw is (more) automated, which could decrease the costs calculated in Table 6.7 (at least for the bigger farms). When the amount of straw given is eaten by the sow, the labour costs will decrease because the removal of dirty straw is not necessary anymore.

Changing the housing of lactating sows

In the basic situation, the lactating sows are in a farrowing crate and their piglets are loose. This situation is compared to one in which the sows and their piglets are loose in a fully slatted stall with a size of 2.08 x 2.60 = 5.40 m^2. When changing the lactating sows to a system where they can be loose with the piglets, the literature agrees on the fact that mortality rate of the piglets will then be higher, but disagrees on the size of the increase. Table 6.8 shows the economic impact when changing to this new housing situation for the farrowing sows. In this stall, 3 different alternatives are calculated for the increase in the mortality rate of the piglets: 14.2%, 15.2% and 16.2% compared to 13.2% in the basic situation.

The extra costs per piglet when changing to this different farrowing housing system are +0.39 ecu, as shown in Table 6.8. This results in a decrease in labour income of 9%. The extra costs per kg fattening pig are 0.005 ecu. Taking into account the alternative that the mortality rate would increase to 16.2%, the total costs per piglet then increase by 2.15 ecu and labour income decreases by 45%. Mortality rate has an important influence on the labour income: 1% increase in mortality rate decreases income by 12%.

So, the fact that mortality rate increases is the most important factor for the decrease in income in this case.

Table 6.8 Economic impact of changing housing for lactating sows (ecus).

			increased mortality rate			16.2%+straw
	basic	**alternative**	**14.2%**	**15.2%**	**16.2%**	**1 kg/sow/day**
Number of sows	165	165	165	165	165	151
Hours labour/sow	14.21	14.21	14.21	14.21	14.21	+1.3
Investment building /sow	2617	2677	2677	2677	2677	2688
Number of sold piglets/sow	21.50	21.50	21.25	21.01	20.76	20.76
Labour costs/sow	243.98	243.98	243.98	243.98	243.98	266.30
Housing cost/sow	353.56	361.67	361.67	361.67	361.67	363.42
Feed costs/sow	395.05	395.05	393.40	391.74	390.09	390.09
Remaining costs/sow	117.49	117.64	117.64	117.64	117.64	126.42
Total cost/piglet	56.71	57.10	56.67	58.26	58.86	60.46
Labour income	14864	13499	11746	9994	8240	5936
% change in labour income	**100%**	**-9%**	**-21%**	**-33%**	**-45%**	**-60%**
Change of cost price per kg fattening pig	**1.580**	**+0.005**	**+0.011**	**+0.018**	**+0.025**	**+0.043**

As an extra welfare measure for the situation in Table 6.8, straw could be provided for the sow and for the piglets. As an example, straw is provided in the alternative where the piglet mortality is 16.2%. More labour is needed to provide and remove the straw. With the lactating sows, the number of stalls to climb in and out of is much higher than within the group housing system. Providing straw to lactating sows, therefore, gives a considerable (additional) decrease in income of 15%.

Weaning age

In Table 6.9 the economic impact of changing the weaning age from 4 (basic) to 5 or 6 weeks is shown. The most important technical parameter when increasing the weaning age is the average number of piglets sold per sow per year, which decreases with increasing weaning age. Moreover, when increasing the weaning age, relatively more expensive farrowing crates are needed. On the other hand, increased weaning age will result in lower feed costs. Sow feed is cheaper than feed for the piglets and increasing the weaning age results in more feed for the sow and less for the piglets. But despite the fact that the total costs per sow decrease, the total costs per piglet sold increase as a result of the lower number of piglets sold. Fewer piglets sold per sow also result in a decrease of total revenue, and hence in a considerable decrease in labour income.

When weaning age increases, more sows can be kept by one person because of a decrease in labour (fewer cycles per sow). From Table 6.9 it can be concluded that, despite that increase in number of animals, a one week increase in weaning age has a big negative economic influence on labour income. Increasing the weaning age from 4 weeks to 5 weeks results in a decrease in income of 44% and an increase in cost price of meat of 0.025 ecu. The highest income is reached at a weaning age of 3 weeks. Changing weaning age could also influence factors such as litter size, fertility and amount of drugs. These factors have not been taken into account in the calculations due to a lack of adequate information.

Table 6.9 Economic impact of changing weaning age (ecus).

Weaning age (weeks)	Number of sows	Investment building per sow	Hours of labour per sow/year	Length cycles (days)	Number of cycles per sow/year	Number of piglets sold per sow /yr	Labour costs per sow per year
3	164	2571	14.30	147	2.39	22.51	245.44
4 •	165	2617	14.21	154	2.29	21.50	243.98
5	166	2663	14.13	161	2.19	20.58	242.65
6	167	2708	14.06	168	2.10	19.73	240.98
	housing costs per sow	feed costs per sow	total costs per sow	total costs per piglet	labour income	**% change in labour income**	**Change of cost price per kg fattening pig**
3	347.33	403.68	1224.36	54.39	22414	**+50%**	**-0.026**
4•	353.56	395.05	1219.37	56.71	14864	**100%**	**1.580**
5	359.73	384.05	1212.23	58.91	8309	**-44%**	**+0.025**
6	365.83	368.05	1200.23	60.83	3141	**-79%**	**+0.047**

• basic situation

Costs of illumination standards

For these costs the results could directly be taken from Den Ouden (1996), who calculated the cost of 20 lux during 12 hours per day. In the default situation, it was assumed that 2 hours per day were used in the farrowing stage. An average illumination of 31, 48 and 44 lux per m^2 was provided in farrowing, gestation and breeding rooms respectively. The costs of providing 12 hours per day at 20 lux were 0.19 ecu per fattening pig. The cost price per kg fattening pig in this case will be 1.580+0.002=1.582 ecu; labour income decrease is 4%.

6.3.4 Economic calculations for the fattening farm

Increasing space per fattening pig

As was the case with the economic calculations for the farrowing farm, the possible effects of increasing space per fattening pig on the technical parameters are not taken into account. The single economic impact of some technical parameters can be found in Appendix 6.2. Increasing the total space per fattening pig is expensive, as shown in Table 6.10, especially because the size of the building is then bigger. Increasing the space per fattening pig from 0.70 (basic) to 0.80 results in 1.16 ecu extra costs per fattening pig. Labour income decreases by 45% and the cost price per kg fattening pig increases by 0.013 ecu. Increasing the percentage of solid concrete floor within the existing total space of 0.70 does not influence the size of the total building. Increasing the amount of solid concrete floor is therefore cheaper than increasing the total space per fattening pig. In the basic situation there is no solid concrete floor available.

Table 6.10 Economic impact of increasing total space and solid concrete floor for fattening pigs (ecus).

Total space	Investment building/ fattening pig	Total costs/ fattening pig	Labour income	% change in labour income	Change of cost price per kg fattening pig
0.70 = base	382	87.73	15608	**100%**	**1.580**
0.80	408	88.89	8561	**-45%**	**+0.013**
0.90	435	90.05	1536	**-90%**	**+0.026**
1.00	461	91.20	-5471	**-135%**	**+0.040**
solid concrete					
0.25	386	87.89	14608	**-6%**	**+0.002**
0.35	390	88.10	13358	**-14%**	**+0.004**
0.50	397	88.41	11482	**-26%**	**+0.008**

Providing straw to fattening pigs

In Table 6.11 there are 3 scenarios calculated:

- Scenario A: No straw and fully slatted floor, the space per fattening pig is 0.57 m^2.

- Scenario B: Half slatted and some straw. Because of a half slatted pen the total space per fattening pig is 0.70 m^2 with 0.35 m^2 solid concrete. Some straw (0.1 kg) per fattening pig per week is provided.

- Scenario C: Solid concrete and straw. Space per fattening pig is 0.70 m^2. In this situation 1.0 kg straw per fattening pig per week is provided (for example the straw-flow system).

Table 6.11 Economic outcome for three different scenarios (ecus).

	A	B	C
Number of fattening pigs	2030	1466	1466
Labour costs/fattening pig	6.65	9.18	9.18
Housing costs/fattening pig	14.95	16.77	17.48
Remaining costs/fattening pig	6.26	6.73	8.12
Total costs/fattening pig	86.18	91.01	93.12
Labour income	24950	7814	-1551
% change in labour income	**100%**	**-69%**	**-106%**
Change in cost price per kg fattening pig	**1.564**	**+0.055**	**+0.077**

Providing straw to fattening pigs has an enormous impact on the number of fattening pigs that can be handled per person. The straw is provided every second day and every second day the dirty straw is removed. In the model a bigger or smaller amount of straw is assumed not to influence the amount of labour required. Going in and out the different stalls causes the major part of time in removing the straw. When the amount of straw given is eaten by the fattening pig the labour costs will decrease because removing the dirty straw is not necessary anymore.

Costs of illumination standards

These results could again be directly taken from Den Ouden (1996), who calculated the costs of 20 lux during 12 hours per day. In the default situation, it was assumed that 1 hour per day was used in the fattening stage. An average illumination of 36 lux per m^2 was provided in the fattening rooms. The costs of providing 12 hours per day of light of 20 lux were 0.36 ecu per fattening pig. The cost price per kg fattening pig in this case was 1.580 ecu + 0.004 ecu = 1.584 ecu. Labour income decreased by 14%.

6.3.5 Differences in economic impact of welfare measures between EU countries

As stated before, all calculations presented so far were done for the Dutch commercial pig farms. To get an idea whether welfare measures will have a different economic impact in other EU countries, additional information has been gathered. Economic and technical parameters, and the current situation regarding the housing situation for sows and fattening pigs, from The Netherlands, France, Italy, Denmark, United Kingdom and Sweden is given in Appendix 6.4. From the point of view of animal welfare measures, it is of particular interest to look at the differences in prices for straw and labour between countries.

From the information in Appendix 6.4, it can be concluded that providing straw in the UK is cheaper than in the Netherlands. In the UK straw and labour are very cheap, which may help explain the high percentage of sows in group housing and farms using straw. Regarding the increase in weaning age, it can be concluded that the higher the revenue price of the piglet the more economic impact there will be on cost price and labour income. The economic impact of increasing the weaning age in Italy, therefore, will have a much bigger economic impact than in e.g. The Netherlands and the UK.

Some countries, such as the UK, already have a major part of the sows in group housing. Changing to a system with only group housing will be easier for them than for a country such as the Netherlands where only 10% of the sows are currently in group-housed facilities.

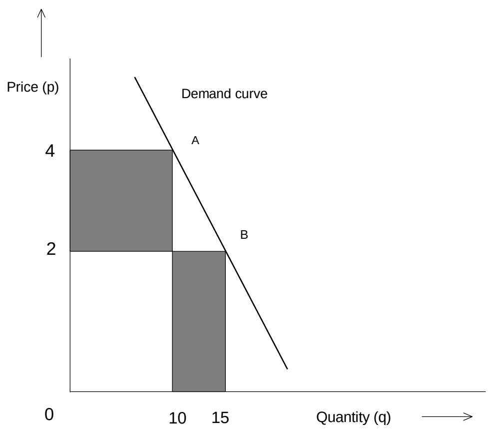
6.4 Price elasticity of pigmeat

In the previous paragraph it was shown that welfare improving measures increase cost price. The question then is how that will affect the consumption of pigmeat. For this, the so-called price elasticity of demand plays an important role. What, precisely, is price elasticity? In the simplest of terms, price elasticity is an indicator of the relative responsiveness (or sensitivity) on the part of producers or consumers to changes in price. A more formal definition of price elasticity is the percentage change in quantity purchased (in the case of demand) or the quantity offered for sale (in the case of supply) in response to a 1-percent change in price (Goodwin, 1994).

Price elasticity = $(\Delta Q/Q) / (\Delta P/P)$ (Q=Quantity and P=Price)

Figure 6.3 is an example of a demand curve with a so-called inelastic price elasticity. When the price increases from 2 to 4, the quantity sold decreases from 15 to 10 (from point B to point A), i.e., $\Delta Q/Q = -5/15=-0.33$ $\Delta P/P=2/2=1$. So, the price elasticity then is -0.33/1= -0.33.

Figure 6.3 A demand curve with an inelastic price elasticity (Dietz *et al.* 1990)



The price elasticity of the demand for most agricultural products is inelastic (between 0 and -1). The closer the elasticity is to 0 the more inelastic it is. In literature, some empirical research was carried out to estimate the price elasticity for pigmeat. Goodwin (1994) summarised the following outcome for the demand of pigmeat in the US.

		Price elasticity of demand
Brandow	Farm Level (1955-57)	0.457
George and King	Farm Level (1946-65)	0.241
Heien	Mkt Level, Not specified(1947-79)	-0.511
Huang	Retail Level (1953-83)	-0.730

Interestingly, these elasticities appear to be remarkably stable over time. Heien's price elasticity for pigmeat is almost identical with the one estimated by Brandow 20 years earlier. This recognises the reality that food consumption patterns change very gradually and only over long periods of time.

Buijtels (1997) was one of the very few who calculated a demand elasticity for pigmeat in the Netherlands, and found a value of -0.341. This outcome is within the range of those found for US conditions.

All the published price elasticities for pigmeat are between 0 and -1. This means that the demand for pigmeat is inelastic. An increase in price of, for example, 10% will give a decrease in demand of less than 10%. This means that, in principle, the total revenue for the pig sector will not decrease because of a higher cost price, as the decrease in demand is (more than) compensated for by the increase in price (Dietz *et al.* 1990).

6.4.1 Consumers behaviour

There has been a questionnaire in 1995 in France and Italy where 1000 persons per country were interviewed. This questionnaire was worked out by the Eurogroup for Animal Welfare. The subject was about the welfare of veal calves (unfortunately no information can be found about such questionnaires for pigmeat). One of the results was that 50% of the people interviewed were very concerned about animal welfare, approximately 30-40% were a little concerned and 10% said that they were not concerned about it at all. More women than men were interested in animal welfare. Another result was that 64% of the French respondents and 45% of the Italian respondents would be prepared to pay between 10-15% more for more humanely produced veal. About 20% of those interviewed in both countries would be prepared to pay 25% more. This is quite substantial, but it is also known that what consumers say that they will do is one thing and what they really do is another. So far, it has been found very difficult to achieve a higher market price for pigmeat produced in a more animal-friendly way (Den Ouden, 1996).

When prices increase, consumers will buy less pigmeat, as shown by the price elasticities. But rather than doing that immediately, consumers make the adjustments more gradually. A classic case of this response to price changes may be seen in the case of pattern of beef consumption during the post Word War II period. As the availability of beef was cyclically expanded, consumers would readily increase beef consumption in response to very modest reductions in real prices. But when the availability of beef was cyclically reduced, consumers were not nearly so ready to accept the change. Very minor reductions in per capita beef availability were met with stubborn resistance and a rapid bidding up of real beef prices as consumers try to maintain their level of beef consumption (Goodwin, 1994).

Once prices reached a level (typically 20-25 percent above the prices that were observed at the end of the increasing consumption phase of the previous cycle) that encouraged the beef industry to embark on the next expansionary phase of the cattle cycle, consumers would again absorb the increased availability of beef with the very modest incentives in the way of price reductions. The statistical analysis of this phenomenon suggested that consumers would complete their adjustment to a reduced beef price in less than three months. But that adjustments to reduced availability and higher beef prices required more than seven years. That is, consumption was not reduced along the same price-quantity demand path as it was increased (Goodwin, 1994). It is only with catastrophic affairs, such as BSE, that consumers respond immediately (and heavily).

With this information, and taking into account a higher cost price for pigmeat because of animal welfare measures, the consumer may not react directly to this higher price but, after a certain period when prices are still higher, it is most likely that they buy less pigmeat and more of another (then relatively cheaper) type of meat.

6.5 Threats from outside Europe

Is there a threat from outside Europe that other countries will enter the European market? For example, in the US pigmeat production is increasing and in this country animal welfare is not considered as important as in Europe. What will happen when the US can export more of their pigmeat to the European market? In this paragraph the US situation will be outlined.

United States of America

Historical data clearly shows that the trend to larger, more specialised pig production and pigmeat processing farms has been ongoing for 60 years or more, but the rate seems to have accelerated in recent years. In 1980, 670,000 farms produced pigs. Only 208,000 such farms remained in 1994, which means nearly 70% had left in 15 years (Hurt *et al.* 1995). Table 6.12 shows the number of farms and the number of pigs by farm size.

Table 6.12 Number of farms and the number of pigs by size groups in the US (USDA, National Agricultural Statistics Service)

	Number of farms and number of pigs by size (head)					
Year	Total	1-99	100-499	500-999	1000-1999	2000+
1992		Percent				
Farms	240,150	60.2	26.5	8.1	3.6	1.6
Pigs	58,202,000	5.3	25.3	22.0	18.9	28.5
1993						
Farms	225,210	61.1	25.3	8.3	3.5	1.8
Pigs	57,904,000	5.0	23.0	21.5	17.5	33.0
1994						
Farms	207,980	59.9	25.5	8.5	3.9	2.2
Pigs	59,992,000	4.5	20.5	20.0	18.0	37.0
1995						
Farms	182,700	59.6	25.1	8.6	4.2	2.6
Pigs	59,694,000	4.0	18.0	18.0	17.0	43.0

Vertically-integrated agribusiness companies are developing production systems which have demonstrated their effectiveness in the broiler industry and are being duplicated in pigmeat production. Economies of scale, disease prevention, and quality management are the steering factors behind the formation of very large production units, whilst availability of feed, land and labour as well as market access, a favourable climate, and a low production density cause the regional shift (Windhorst, 1994).

More reasons for the changing US pigmeat industry (Hurt *et al.* 1995):

- The pigmeat industry in the US is known as a high margin business. High returns have attracted outside investors.
- Some producers know how to consistently operate at low costs.
- The industry is now highly technical and technologically dynamic. New technologies have names such as All-In/All-Out, Multiple-Site Rearing, Segregated Early Weaning, Split-Sex Feeding, Phase Feeding, Artificial Insemination, and Enhanced Genetics. These technologies are health enhancing, cost lowering, and risk reducing, allowing greater and greater concentrations of pigs.
- Much of the new technology cannot be fully implemented using the existing physical and human resources in traditional pig areas.

- Additional economic benefits can be gained from improved co-ordination of a stable supply of consistent quality pigs through processing and by better matching pigmeat production to consumers desires.
- Many in the industry believe that domestic and foreign consumers will demand more highly differentiated pigmeat products in the future, perhaps requiring co-ordinating mechanisms other than spot markets and including contracting and vertical co-ordination.

With lower costs, increased co-ordination, and improved quality, the pigmeat industry could have a net growth of 15% over the next decade (Hurt, 1995). The export volume has already increased during the last years (see Table 6.13), and is expected to increase more in the future.

Table 6.13 Important importing and exporting countries of pigmeat in the world.

Country	Export/Import	kg pigmeat (million)		
		1995	1996	1997[1]
European Union	Export	850	839	896
	Import	72	36	42
United States	Export	350	416	475
	Import	301	280	[2]
China	Export	272	340	[2]
Japan	Import	829	887	914
GOS	Import	553	680	747
East-Europe	Import	119	88	84
Korea	Import	90	110	[2]

[1] Estimation [2] Not available

For the EU, the most important countries to export pigmeat to are Japan, Russia and Poland. The leading country in the EU for total export of pigmeat (all over the world) is Denmark with 876.91 million kg followed by The Netherlands with 821.29 million kg and Belgium + Luxembourg with 521.82 million kg (Appendix 6.1).

The cost price of producing fattening pigs in the US is already considerably lower than in Europe (Hurt, 1995). Putting more demands on animal welfare in Europe will place the US in this respect in an even more favourable position. Now that the US has become an exporting country and when - under new GATT/WTO regulations - they are allowed to further enter the European Market, they will become a major concern for the European pig industry. GATT/WTO does not have (yet?) any legislation to close borders for meat that was produced under less strict animal welfare conditions, in contrast to meat from countries with highly contagious diseases.

6.6 Conclusions

88. Some measures and housing systems whose aim is to improve animal welfare, increase the cost price of pigmeat and hence reduce farmers' income, whilst other measures have no cost or are even cost beneficial. However even very small increases in cost price can decrease income considerably. In the model examined an increase in cost price of 1% decreases income by 30 to 50%.

89. The cheapest form of group housing for pregnant sows is cheaper from a per-sow investment point of view than the commonest individual housing system. However, this benefit would be outweighed by relatively small production differences, e.g. a 0.1 decrease in number of liveborn piglets per litter or a 3-4% increase in the annual culling rate of the sows.

90. Provision of straw for sows and fattening pigs, increased weaning age of piglets and increased space for sows and pigs are all relatively expensive ways to improve animal welfare. Providing more illumination is relatively cheap, and concrete floors instead of slatted ones is intermediate in this respect. In countries where labour and straw are relatively cheap, as is the case in the UK, the economic ranking of the measures may be different.

91. Most consumers are unlikely to be willing to pay more for pigmeat that is produced under conditions which they perceive to be better with respect to animal welfare. Therefore, there will be a serious threat to income and employment in the EU pig industry, due to a decline in competitiveness with respect to export on the world market on the one hand and the possible import of pigmeat from third countries where animal welfare standards are lower on the other. Restrictions on such imports may cause the EU difficulties because of GATT/WTO agreements. An example of such a threat is the US, although their cost price is already much lower in any case.

92. If consumers are not willing to pay for better animal welfare when imports from third countries where animal welfare standards are lower cannot be restricted, then the pig industry has no choice but to try to counterbalance the increase in costs, for example by increasing the herd size and improving economic efficiency.

93. The possibility that consumers will cease to buy pig meat if the welfare of pigs is perceived to be unacceptably poor should be considered although data concerning this point are not available at present.

APPENDIX 6.1

Export of pigmeat between EU countries, 1995, kg pigmeat (*million) excl. bacon (Source: Product Boards for Livestock, Meat anc

To / From	Danm	Neth	B+L	France	UK	Ger	Spain	Ireland	Italy	Austr	Sweden	Finland	Gr
Danm	------	13.17	2.40	106.47	73.50	219.33	4.29	1.22	96.50	2.41	14.96	10.29	19.
Neth	7.49	------	37.64	77.15	14.84	336.50	12.11	0.92	220.20	12.29	0.30	0	54.
B+L	2.18	25.30	------	73.43	8.15	311.69	8.53	0.38	68.76	2.56	0.35	0	9.
France	7.28	5.47	14.99	------	38.88	50.17	14.54	3.94	132.88	0.14	1.96	0	17.
UK	2.72	7.76	5.99	16.48	------	55.82	0.89	3.69	17.68	0	2.28	0	0.
Ger	2.96	11.50	2.30	7.38	3.86	------	1.54	0.76	65.13	9.09	0.36	0.03	2.
Spain	2.48	1.77	0.33	32.21	0.78	24.79	------	0.02	10.21	0.01	0.03	0	1.
Ireland	2.14	1.61	0.17	7.14	32.86	11.9	0.25	------	6.23	0.01	0.56	0	0
Italy	0.29	3.16	0.50	20.22	0.02	18.71	0.76	0.02	------	2.63	0.30	0	0.
Austr	0	0.23	0.04	0	0	3.33	0.04	0	25.93	------	0	0	0.
Sweden	1.51	0.05	1.06	0.80	1.24	0.95	0	0	2.44	0	------	3.56	0.
Finland	0.09	0.03	0	0.02	0.23	0	0	0	0	0	1.37	-------	0.
Greece	0.34	0.08	0.05	0.01	0	0.01	0	0	0	0	0.05	0	----
Portug	0	0.02	0.01	0.06	0.07	0.23	0.24	0	0.11	0	0.02	0	0

APPENDIX 6.2 ECONOMIC IMPACT OF TECHNICAL PARAMETERS

FARROWING FARM

Changes in mortality rate before weaning (ecus)

Standard Mortality Rate	Changed Mortality Rate to:	Number of Cycles/ Sow/year	Number of sold piglets /sow/year	Costs per sold piglet	Labour income	**% change in labour income**	**Change of costs per k fattening pig**
13.2%	**13.2%**	2.29	21.50	56.71	14864	**100%**	**1.580**
13.2%	**14.2%**	2.29	21.25	57.28	13080	**-12%**	**+0.006**
13.2%	**15.2%**	2.29	21.01	57.87	12660	**-24%**	**+0.013**
13.2%	**16.2%**	2.29	20.76	58.47	9513	**-36%**	**+0.020**

Conclusion: a 1-% increase in mortality rate before weaning leads to 0.57 ecu extra costs per piglet, 12% decrease in labour income and 0.006 ecu extra costs per kg fattening pig

Changes in mortality rate after weaning (ecus)

Standard Mortality Rate	Changed Mortality Rate to:	Number of Cycles/ Sow/year	Number of sold piglets /sow/year	Costs per sold piglet	Labour income	**% change in labour Income**	**Change of cos per kg fattenin pig**
1.5%	**1.5%**	2.29	21.50	56.71	14864	**100%**	**1.580**
1.5%	**2.5%**	2.29	21.28	57.21	13377	**-10%**	**+ 0.006**
1.5%	**3.5%**	2.29	21.07	57.73	11891	**-20%**	**+ 0.012**

Conclusion: a 1-% increase in mortality rate after weaning leads to 0.050 ecu extra costs per piglet, 10% decrease in labour income and 0.006 ecu extra costs per kg fattening pig.

Changes in number of liveborn piglets/cycle/sow (ecus)

Standard # liveborn piglets/cycle /sow	Changed to:	Number of Cycles /Sow/year	Number of sold piglets/ sow/year	Costs per sold piglet	Labour income	**% change in labour income**	**Change c costs per k fattening pig**
11.0	11.0	2.29	21.50	56.71	14864	**100%**	**1.580**
11.0	**10.0**	2.29	19.55	61.28	2555	**-83%**	**+0.053**

Conclusion: the number of liveborn piglets has a big impact on labour income. A decrease of 0.1 in liveborn piglets per cycle results in a 8-% decrease in labour income and 0.005 ecu per kg fattening pig extra costs.

Changing percentage of different culling reasons (ecus)

No oestrus	Sickness accidents	Lameness/ leg weakness	Replacement Percentage	Costs per sold piglet	Labour Income	**% change in labour income**	**Change of costs per kg fattening pig**
4%*	7%*	5%*	40%*	56.71	14864	**100%**	**1.580**
5%			41%	56.82	14551	**-2.1%**	**+0.001**
	8%		41%	56.85	14477	**-2.6%**	**+0.001**
		6%	41%	56.81	14596	**-1.8%**	**+0.001**

*basic

Conclusion: a 1-% increase in culling results in a 2-3 % decrease in labour income. There are some differences between reasons for culling.

FATTENING FARM

Changes in growth/day (ecus)

Growth	Feed conversion efficiency	Costs/ sold pig	Labour income	**% change in labour income**	**Change of costs per kg fattening pig**
737	2.82	87.75	15608	**100%**	**1.580**
727	2.84	88.53	11151	**29%**	**+0.009**
717	2.86	89.27	6989	**55%**	**+0.017**

Conclusion: a 10 gram per day change in growth rate results in a decrease in income of about 30%. The cost price per kg fattening pig increases by 0.009 ecu.

Changes in mortality (ecus)

Mortality	Costs/sold pig	Labour income	**% change in labour income**	**Change of costs per kg fattening pig**
2.4	87.75	15608	**100%**	**1.580**
2.6	87.85	14380	**-8%**	**+0.001**
2.8	87.96	13151	**-16%**	**+0.002**
3.0	88.06	11920	**-24%**	**+0.004**
3.4	88.28	9455	**-39%**	**+0.006**

Conclusion: a 1-% change in mortality leads to 39% decrease in income.

APPENDIX 6.3 BASIC COMMERCIAL FARM THE NETHERLANDS

TECHNICAL PARAMETERS SOWFARM

Variable	Value
Number of sows	165
Hours of labour /sow/year	14.2
Investment building per sow	2617 ecu
Occupation rate	0.918
Number of open days per average sow	11
Days lost per culled sow	31
Days lost per average sow	17
Replacement rate sow	40%
Time between 2 cycles (days)	154
Number of cycles/sow/year	2.29
Number of sold piglets/ sow/year	21.50

ECONOMIC PARAMETERS SOWFARM (per sow per year)

Variable	Value	
Labour costs	244	ecu
Housing costs	354	ecu
Depreciation	257	ecu
Interest	97	ecu
Feed costs	395	ecu
Interest costs	27	ecu
Health costs	32	ecu
Insemination costs	24	ecu
Price difference buying gilts and selling sows for slaughter	26	ecu
Remaining costs [1]	117	ecu
Total costs	1219	ecu
Total costs per sold piglet	57	ecu
Revenue piglet	50	ecu
Net result per sold piglet [2]	-7	ecu
Labour income [3]	14864	ecu

TECHNICAL PARAMETERS FATTENING FARM

Variable	Value
Number of fattening pigs	2009
Hours of labour per fattening pig	0.39
Investment building per fattening pig	382 ecu
Occupation rate	0.938
Live weight end fattening	113 kg
Feed conversion	2.82
Average number of rounds per year	2.91
Number of sold fattening pigs	6077

ECONOMIC PARAMETERS FATTENING FARM

Variable	Value	
Labour costs per fattening pig	6	ecu
Housing costs per fattening pig	16	ecu
Depreciation	12	ecu
Interest	5	ecu
Feed costs	52	ecu
Interest costs	2	ecu
Health costs	2	ecu
Transportation costs	3	ecu
Remaining costs [1]	6	ecu
Total costs fattening pig	88	ecu
Costs fattening pig included piglet costs	139	ecu
Meat price per kg	1	ecu
Revenue per fattening pig	133	ecu
Net result fattening pig	-4	ecu
Labour income [3]	15608	ecu

[1] Remaining costs = Administration costs, insurance, taxes, manure costs, heating, water, electra and straw.
[2] Net result per sold piglet = Revenue piglet-total costs piglet
[3] Labour income = Net return to labour and management per year = Returns - costs excl. costs for labour

APPENDIX 6.4 INFORMATION ABOUT COMMERCIAL PIG FARMS IN EU

	Country (ECU)					
	Neth[1]	Fran[2]	Italy[3]	DK[4]	UK[5]	Swed[6]
GENERAL ASPECTS						
Wages/hour for a farmer	17	13	12	19	9	16
Interest rate	6.8%	7.5%	11%	8%	8.1%	6%
Price straw per ton	86	57	88	67	43	38
Revenue price pigmeat per kg	1.53	1.37	1.69	1.53	1.59	1.49
Revenue price piglet	49.6	58.9	67.9	55.0	49.1	51.5
Feed price per 100 kg sow	19	20	21	19	22	20
piglets	31	31	33	27	42	25
fattening pigs	20	18	22	19	25	19
Number of: sows per person (full time)	165	150	150	130	130	120
:fattening pigs per person (full time)	2000		2000	2000	1659	1500
FARROWING STAGE						
Investment per sow	2636	1973	2574	2148	2383	4395
Weaning age (days)	28	27.2	28	28	24.8	39
Total mortality rate piglets	14.4	18.1	17.4	12.7	11.7	18.1
Number of weaned piglets per sow/year	21.50	21.8	19.2	22.0	21.9	19.8
Age of selling to fattening stage (days)	70	72	90	75	72	84
Hours of labour per sow per year	14.2	17.8	20	13.3	17.7	15
Sow replacement rate	40%	40%	36%	40%	43	45%
Feed costs/sow/year (included piglets)	394	486	592	466	288	450
FATTENING STAGE						
Investment per fattening pig place	381	258	103	308	236	440
Weight pig at start fattening (kg)	25	31.3	30	30	43	29
Live weight when ready to slaughter (kg)	113	108.5	160	100	95	110
Slaughter weight (kg)	87	84.6	128	75	71	81
Average growth (gram) per day	737	737	600	750	703	830
Feed conversion(kg feed per kg growth)	2.82	2.89	4.00	2.70	2.65	2.9
Mortality rate (%)	2.4%	3.6%	4.0%	3.0%	2.9%	1.6%
Feed costs per fattening pig	52	40	103	34	53	45
Hours of labour per sold fattening pig	0.39	0.40	1.0	0.20	0.69	0.4
HOUSING FACILITIES						
Pregnant sows: Sows confined	30 %	22%	5%	34%	15%	
Sows in crates	60%	41%	63.5%	54%	20%	
Sows in group housing	10%	37%	31.5%	12%	69%	
Lactating sows: Sows confined	40%	33%	± 1%	40%	9%	
Sows in crates	60%	58%	99 %	60%	86%	
Sows loose with piglets	± 1%	9%*	-	1%	10%	
Fattening pigs: Fully slatted floor	15%	55%	40%	55%	21%	
Partly slatted floor	85%	35%	30%	43%	41%	
Concrete floor	-	10%	30%	2%	38%	
Farrowing and Fattening						
%farms with outdoor housing	± 1%	9%	± 1%	2%	24%	
%farms using straw	± 1%	-	± 1%	15%	65%	

*outdoor housing

Sources of information
[1] Research Institute Pig Husbandry Rosmalen, information housing facilities from G. Backus.
[2] Institute technique du proc
[3] Associazione Nazionale Allevatori Suini
[4] Danske Slagterier
[5] British Pig Association
[6] Slakteriförbundet SCAN

CHAPTER 7. FUTURE RESEARCH

The following is a list of topics which require further research. More knowledge is needed. The list is not in order of importance and is not exhaustive. The fact that a specific subject figures on this list does not mean that there is no knowledge in the area but indicates that further work is useful.

1. Further studies are necessary on the biology of the pig including behaviour as well as on the health and hygiene relative to different husbandry systems, in particular on seminatural conditions, in order to improve understanding of the needs of pigs.

2. The relationships be tween welfare and the consequences in the brain of abnormal behaviour, particularly inactive and unresponsive behaviour.

3. Development of sensitive and specific laboratory tests, which are easy to handle, aiming at early detection of infection. This is central for disease prevention, including endemic diseases.

4. Studies of risk factors for the most prevalent enzootic (endemic) health diseases. The following problems should be particularly considered:

   - Respiratory disorders in fattening pigs
   - Leg/locomotor problems in breeding sows
   - Periparturient disorders, such as MMA, stillbirth, weak/hypotrophic pigs at birth
   - Digestive disorders
   - Abnormal behaviour, such as tail- and ear biting.

5. Further development of epidemiological tools and methods for both health measurement and decision-making for prevention.

6. Assessment of the consequences of growth promoters on welfare.

7. Antibiotics in feed and antibiotic resistance

8. Welfare aspects of early weaning of piglets (before 21 days of age). In such evaluation, it is important that the welfare aspects of the early weaning are distinguished from effects of multi-site rearing, moving the piglets to new sites. Studies should specifically consider behavioural signs of maternal deprivation in the piglets, such as belly-nosing.

9. Effects of high stocking density on the welfare of pigs.

10. Effects of continuous loud noise on the welfare of pigs.

11. The importance of the brightness and duration of light for pig welfare.

12. Welfare aspects, from the sow perspective, of nursing large litters (in connection with hyperprolificacy).

13. Physiological measurement of pain and inflammation.

14. Indicators of chronic stress.

15. Determination of the extent to which tail docking results in chronic pain.

16. Development of practical working methods for analgesia/anaesthesia of piglets in connection with castration.

17. Interactions between genetically produced changes in both muscle anatomy and cardiovascular function and physiological responses to activity in pigs.

18. Determination of the space requirement of the individually-housed adult breeding boar.

19. Aspects of welfare in the breeding sow, such as body condition effects.

20. Relationship between type of flooring-bedding on salmonella infection and salmonella survival in growing-finishing pigs.

21. Further development of group-housing systems for pregnant sows, where negative welfare effects of group-housing, such as aggression in connection with mixing, can be reduced or eliminated.

22. Effects of type of housing during the pregnancy period on the welfare of the farrowing-lactating sow.

23. The impact of stall design and flooring on the welfare of the confined pregnant sow.

24. Studies of the recognition of sows by other sows after periods of separation and its relevance to aggression and the mixing of sows.

25. The extent to which acute pre-farrowing stress in sows in farrowing crates is attributable to confinement or to lack of manipulable substrates.

26. Further development of loose-house systems for farrowing-lactating sows, which meet the needs of the sow without compromising piglet survival.

27. Welfare consequences for the sow being confined for the whole or part of the lactation period.

28. Studies on hunger in sowsincluding the role of bulky and high energy food.

29. The relative roles of different feeds, possibilities to root or manipulate and housing conditions in improving sow welfare.

30. Efects of different space allowances on the welfare of pigs between weaning and slaughter.

31. Studies on the prevalence of tail and ear-biting in strawless systems for growing/finishing pigs.

32. Effects of different group sizes and group structures on the welfare of growing/finishing pigs.

33. Consumer attitudes and behaviour towards pig meat in the case of no improvement or only minor improvement in the welfare of pigs.

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

The following chapter summari ses the main contents and conclusions of the previous chapters and contains the recommendations which can be made on the basis of the scientific review. Each recommendation is presented in the context of the summarised scientific evidence leading to the recommendation.

General welfare aspects of pig housing and management

1. Pigs have needs which must be fulfilled in order to safeguard their welfare. Such needs include obtaining adequate nutrients, performing certain species-specific behaviours, taking sufficient exercise and adopting adequate movements and postures to avoid maldevelopment of muscles, bones and joints, avoiding injuries, disease and parasitism, and living in adequate social surroundings.

2. Recommendation: The person responsible for the pigs should ensure that their welfare, including their health, is safeguarded by the use of appropriate housing, feeding, care, vaccination, preventive medicine and veterinary advice and treatment. Pigs should be inspected daily by the caretaker for signs of poor welfare, such as bodily condition, movements and postures, condition of skin, eyes, ears, legs, feet, and tail. Other signs of ill health include listlessness, loss of appetite, laboured breathing, excessive salivation, vaginal discharge, frequent coughing, swollen joints, lameness and scouring. Attention should also be paid to the presence of external parasites, to the condition of faeces and to feed and water consumption.

3. The welfare of pigs is assessed by a combinations of a variety of methods, including behavioural measurements, such as preference tests, aversion tests, measures of motivation and abnormal behaviour, physiological measurements, health measurements and performance measurements.

4. Conclusions about welfare should always be based on all available evidence, properly weighted, and should not rely only on, for example, preference or other trials in experimental conditions, or epidemiological surveys. When recommendations about modified practices are produced, the relevance of experimental studies where effects of only one or a few factors have been varied, must be carefully considered. On practically operating farms, effects of such single variables may be exaggerated or compensated by other factors, and the stockman factor is central in the effective functioning of a particular system. It is therefore normally desirable that on-farm surveys are carried out before definite recommendations are issued.

5. When kept under free-range conditions, pigs live in small social groups, show a variable diurnal rhythm and have strongly developed exploratory behaviour. At birth, sows farrow in social isolation and construct a nest prior to parturition. Weaning is gradual, is completed only after about 13-17 weeks, and piglets are gradually integrated into the herd with little obvious aggression. It should be borne in mind that selection has modified many aspects of pig biology.

6. A variety of different husbandry systems are in commercial use. Pig herds may specialise in piglet production ("sow herds” or "breeding herds”), in production of slaughter pigs from purchased piglets ("fattening/finishing/feeding herds”) or may have both functions in the same unit ("farrow to finish herds”). Within each type of enterprise, there are several different possibilities for housing systems, depending on national legislation, regional conditions and economic circumstances.

Specific factors in housing and management

7. The needs of pigs which are affected especially by artificial f looring are: to have comfort when lying and avoidance of injury, to minimise the risk of disease, to thermoregulate adequately in any high or low temperatures which might be encountered. Where floors are perforated or slatted, rather than solid, hygiene may be improved by reducing the contact between the pig and the faeces/urine. The risk for claw injuries is less on solid flooring than on perforated flooring. Some perforations or slats in floors may trap claws and the solid section between perforations or slats may be too narrow to support the foot evenly.

8. Recommendation: The size, construction and maintenance of slats, slots and perforations should be suitable for the size of the claws of the pigs kept on that floor, in such a way that the likelihood of trapping, discomfort whilst standing or walking and injury is minimised.

9. Pigs have a preference for insulated or bedded flooring providing physical and thermal comfort. In hot conditions, possibilities for being cooled by the floor may be more important to the pigs than physical comfort or insulation provided by a bedded area. Hence deep litter or compost systems may create thermoregulatory problems in pigs kept under high ambient temperatures.

10. Bedded flooring not only influences comfort, it also provides for investigatory and manipulatory activities and, in the case of straw, may provide dietary fibre and allow pigs to express feeding behaviour. Only straw of good hygienic quality should be used.

11. Earth floors suitable for rooting and objects or materials for manipulation and exploration provide environmental enrichment in barren housing. Deformable materials, such as wood with bark on it or thick rope, is especially attractive to pigs. When artificial objects are provided, however, the interest in manipulating these objects decreases as a function of decreased novelty.

12. Recommendation: Pigs should be able to choose appropriate functional conditions. Except in buildings where the temperature is adequately controlled, pigs should also be able to choose appropriate thermal conditions.

13. Recommendation: All pigs should be provided with a lying surface which is physically and thermally comfortable and which does not result in injuries. Materials for investigation and manipulation, which may be bedding material or earth floors suitable for rooting but need not be, should be provided whenever possible for pigs.

14. Apart from adult boars and sows around parturition, pigs are social animals.

15. Recommendation: Pigs should not be housed in social isolation, except for mature boars and sows at farrowing. [see also recommendation no. 64]

16. The welfare consequences of keeping pigs in large groups (more than about 15-20 pigs for growing finishing pigs and sows) are not well understood. Adequate individual inspection is important for welfare and is more difficult with large groups.

17. Recommendation: When pigs are kept in large groups, sufficient measures must be taken to allow individual inspection of the animals.

18. In general, the mixing of pigs results in poor welfare. The younger the pigs, the less severe are the effects on welfare of mixing pigs.

19. When mixing pigs, the welfare is often better if the pigs are uniform in weight. Even if the immediate post-mixing aggression levels may be higher in uniform groups, size uniformity minimises the undesirable consequences for welfare of competition, especially that for food. When pigs are mixed, their welfare is better when they have adequate opportunities to withdraw and hide from other pigs.

20. Recommendation: The mixing of pigs, unfamiliar with one another, should be avoided whenever possible. If pigs have to be mixed, this should be done at as young an age as possible, preferably before weaning. When pigs are mixed, they should have adequate opportunities to escape and hide from other pigs.

21. The use of tranquillizing drugs, such as Azaperone and Amperozide, can be useful in order to reduce the immediate aggression and stress caused by mixing. However, their effects are limited in time, to a few hours at most, and when their effects stop, the mixed pigs often engage in agonistic interactions of the same magnitude as untreated groups.

22. Pigs which have been treated with tranquillizers at mixing do not differ from untreated pigs with regard to growth rate and performance as a whole.

23. Recommendation: The use of tranquillizing drugs in order to facilitate mixing should be limited to exceptional conditions and never be a routine treatment.

24. Pigs do not work hard to remain in light, although prefer to have light when feeding. Some normal behaviour of the pigs (e.g. exploration) requires that light should be on for longer than the feeding period. Proper lighting is also necessary to facilitate inspection.

25. Recommendation: Pigs should never be kept in environments with constant darkness. It is not acceptable to provide light only during brief periods, for example feeding and inspection. Cycles of light and dark should be used so that the pigs have ample opportunities to carry out their normal behaviour and dark periods are provided during the resting time of the pigs, i.e. during night. It seems reasonable to provide a light period of approximately 8 hours or more each day. Minimum light intensities

should allow pigs to see well enough to distinguish small objects and subtle visual signals, and should allow for adequate visual inspection. Light levels of 40-80 lux are sufficient to allow this.

26. The thermoneutral zone of a pig varies with its age, size and nutritional status, and with other environmental variables, such as draught. The welfare of a pig is best when it has access to an environment where the ambient temperature is within its thermoneutral zone.

27. Recommendation: Every effort should be made to provide pigs with an area in which they can maintain thermal comfort. When pigs are kept outside in areas without natural shelter or shade, some form of protection from the weather and from sunshine should be provided. In hot weather, pigs kept outside should have access to a source of evaporative cooling such as a wallow, although care would then be needed to minimise disease risk.

28. Dusty environments and high concentrations of ammonia and other irritating gases cause harmful effects on the respiratory system. Dry air too can be an irritating factor, increasing skin evaporation and lowering skin temperature.

29. Recommendation: Recommended maximum levels for noxious gases are: ammonia 10 ppm, carbon dioxide 3000 ppm, carbon monoxide 10 ppm, hydrogen sulphide 0.5 ppm. Pigs should be maintained in a moderately high humidity and very high dust levels should be avoided.

30. High levels of noise can be generated by mechanical devices or the animals themselves, and are associated with signs of poorer welfare.

31. Recommendation: Continuous noise in pig houses should be kept low and continuous noise levels as loud as 85 dBA should be avoided.

32. The welfare of pigs appears to be negatively affected by strong reduction of available space and this occurs at all ages. Crowding causes negative effects on physiology, behaviour and, production.

33.. The necessary space for a pig to be able to lie down in lateral recumbency can be calculated by the formula: Area (m^2)=0.047 x Liveweight $^{0.67}$. When the available space has been 0.03 x Liveweight $^{0.67}$ m² per animal, no negative effects on performance have been detected.

34. Recommendation: The space available to pigs of different categories should provide room for all pigs to lie at the same time in lateral recumbency. It should be remembered that pigs in groups, will in many conditions, be able to share the available space. Other factors such as temperature, group size and type of building will affect the actual space requiremant.

35. Lack of feeding space is a potential source of aggression and poor feed conversion. Provision of food ad libitum reduces agonistic competition at feeding times and reduces differences in food intake between individuals. Moreover, feeding *ad libitum* allows a reduction of the minimum trough space.

36. Recommendation: The minimum space (trough length) for groups of pigs fed restrictively at the same time e.g. at a single trough, should allow all animals to feed simultaneously and in any case the minimum length of the feeder should be expressed by the equation:
Length (mm) = 60 x liveweight $^{0.33}$

37. Castration is carried out principally to avoid boar taint in meat but also to reduce fighting. It is not necessary if animals are slaughtered before these maturational changes occur. Castration using surgical means causes prolonged pain which is likely to be worse if there is tearing of tissues. This pain could be reduced by cutting tissue and not tearing it and by anaesthesia or analgesia. Effective anaesthesia and analgesia are possible but further information is needed on whether or not there are side effects. Further information is needed on alternate means of castration.

38. Recommendation: Castration by a means which does not involve pain and other aspects of poor welfare would be acceptable. Surgical castration should be carried out using sufficiently long acting analgesia provided that it is demonstrated that the benefits for welfare of using these are greater than any adverse effects on welfare. The tearing of tissue when the testes are removed should be avoided unless prolonged analgesia is possible. Other new techniques would be acceptable their net benefits for welfare outweighed any disadvantages for welfare.

39. Tail docking is likely to be painful when it is carried out and it has been demonstrated that in a proportion of animals it leads to neuroma formation and hence to prolonged pain. Damaging effects of tail-biting can be reduced by tail-docking, probably because the docked tail is very sensitive and hence more rapidly removed if taken into the mouth of another pig.

40. Recommendation: The problems of injury following tail-biting should be solved by improved management rather than by tail-docking.

41. Tooth-clipping and tooth grinding are likely to cause immediate pain and some prolonged pain. Tooth grinding causes less tooth fracture than tooth clipping. It is desirable that management systems in which tooth-grinding or tooth-clipping are not needed are designed or that pain is minimised using analgesics. Ear-tagging and ear-notching may be painful to the pigs. Nose-ringing is painful as well and affects sensitive tissue of the pigs.

42. Recommendation: Tooth-grinding rather than tooth clipping should be used but efforts should be made to avoid the necessity for either. Ear-tagging should be carried out in such a way that the area of tissue damage and resulting poor welfare are minimised and the cutting of notches, or other wounding of the ears of pigs for marking purposes, is acceptable only if the total cut area is no greater than that which would be caused by a well-designed ear tag. Nose-ringing should be avoided whenever possible and animals should never be pulled by a nose ring.

43. The quality of stockmanship has large effects on the welfare of pigs in any housing system. A skilful stockman can compensate for many bad effects of certain housing systems and a poor stockman cause problems in an otherwise good system.

44. Recommendation: Every person who is in charge of pigs should be licensed for this occupation. Such licensing should follow proper training and certification.

45. Infectious diseases are important welfare problems. Effective health-care therefore requires that pigs are kept in an appropriate environment. Strong measures, for example good hygiene and careful routines with purchased pigs, can help in avoiding infection of herds with pathogenic micro-organisms.

46. Many diseases are multi-factorial and , even when there is an infectious agent, their development depends on the husbandry conditions of the pigs. Effective health care therefore requires that pigs are kept in environments which do not cause stress and immune system inadequacy .

47. Recommendation: Herd health is best if animals from different farms are not mixed together. However, where such mixing is necessary, appropriate isolation and other treatment to minimise cross infection is necessary. In order to minimise disease in all pigs, they should be kept in environments which do not cause stress and reduced immunocompetence.

48. Selection for large muscle blocks and fast growth has led to leg problems, cardiovascular inadequacy during periods of high metabolism and increased risk of mortality and poor welfare during handling and transport. Although some of these problems have been addressed, there are important welfare problems which are attributable to the selection procedures.

49. Recommendation: No selection should occur without reference to the effects of that selection on welfare of piglets, growing and finishing pigs and breeding animals. The continuation of new genetic lines in which the welfare of the animals is, on average, worse than that of existing lines should not be permitted.

50. Body composition at selection has an important role in lifetime reproductive efficiency. Genetic selection of fast growing lean pigs has led to impressive gains in the lean tissue deposition. Little attention has been given to feed intake and the modern genotypes may in fact be too thin.

51. Recommendation: Nutritional input and strategies must be targeted towards meeting the specific requirements of the animal and ensuring good welfare.

52. Selection programmes where halothane positive genetic lines for more lean meat and better ham shape are maintained, increase the prevalence of stress susceptible pigs. The pathogenesis of osteochondrosis is not well understood but high growth rates appear to be one important risk factor.

53. Recommendation: Even where some production lines will be lost, a strategy aimed at eliminating the halothane gene from breeds or lines is necessary. Genetic selection programmes should include selection against osteochondrosis and other health disorders.

54. Selection for prolificacy is leading to increased numbers of piglets being born alive but of low birth weight and hence to an increased proportion of piglets dying before weaning age is reached. Piglet weakness and consequent mortality is a serious welfare problem.

55. Recommendation: Selection for prolificacy should be accompanied by selection for increased piglet rearing capacity in sows such that there is no increase in the proportion of piglets born alive which suffer or die before weaning.

56. Surprisingly, work on the welfare of transgenic pigs or pigs treated with substances produced by recombinant DNA technology is not abundant in the scientific literature.

57. Recommendation: Evaluation of transgenic animals should include overall performance tests involving scientific studies of welfare as well as production and reproduction traits. The evaluation should be done under practical field conditions for at least two generations.

58. Growth promoters can be divided into different families of compounds and they are submitted to specific regulations or recommendations. For most growth promoters, there is a lack of documentation about the welfare consequences of their use.

59. The widespread use of antibiotics and chemobiotics for the purpose of growth promotion and for preventive medication leads to risks for development of resistant strains of bacteria. The development of such strains is a potential welfare problem for all animals including man.

60. Recommendation: Growth promoters which cause negative effects on welfare, including health, should not be used.

61. Recommendation: Routine preventive medication with antibiotics and chemobiotics should not be carried out.

Housing systems for pigs

62. The mixing of mature boars can cause severe welfare problems due to damage during fighting.

63. The mixing of unfamiliar sows may cause welfare problems because of fights between the animals.

64. Recommendation: Neither boars nor gilts should be reared in social isolation. It is acceptable to house boars individually, but they should not be permanently housed in visual and olfactory isolation from other pigs. The dimensions of individual pens for mature boars should correspond to the weight and size of the pig. The mixing of mature boars should be avoided and carried out only when essential, and under close supervision. Mixing of unfamiliar sows will be necessary if group housing systems are adopted. The immediate post mixing period should be supervised and methods to minimise aggression should be applied.

65. Mating in a confined space where the sow cannot escape the courting attempts of the boar may cause welfare problems.

66. Recommendation: Mating areas should be smooth-sided with non-slip flooring and have a minimum diagonal length of 3.9 m. Mating should be supervised if it takes place in a confined space where the sow cannot escape from the boar.

67. Semen collection and artificial insemination procedures have potential risks for causing injuries and infections to the genital tracts of the animals.

68. Recommendation: Semen collection and artificial insemination procedures should be carried out only by trained and competent persons.

69. Some welfare problems of dry sows can occur in several different kinds of rearing conditions. The food provided for dry sows is usually much less than that which sows would choose to consume, so the animals are hungry throughout much of their lives. Energy intake has to be limited in dry sows to prevent the detrimental effects of obesity, but too low a feed level causes very poor welfare. This problem can be alleviated by giving bulky food , and in some cases, this can also supply the need for manipulable material.

70. Recommendation: All sows should be given sufficient food for maintenance, growth and piglet production. All sows should be given some bulky or high fibre food as well as high energy food in order to reduce hunger as well as to provide for the need to chew. The high energy food can be fed once per day in a single meal but bulky or high fibre food should be available for longer periods.

71. The advantages for welfare of the confinement of sows in stalls over group-housing of sows are as follows; since pigs are not mixed, fighting with associated stress and injuries is prevented, each sow is certain to have the full ration of food available to her, sows can all feed at the same time, care-taking is made easier and signs of morbidity , such as feed refusals or vulval discharge , are easy to detect and can then be treated appropriately.
The major disadvantage of group-housing is that injuries such as bites to the vulva or skin can occur , and it is also possible for these sows to slip on the floor. Fighting or injury could lead to embryo loss in extreme cases, and detection of health problems is more difficult. In general, better stockmanship is necessary to prevent these adverse affects.

72. The advantages for welfare of group-housing sows rather than confining them in stalls are that: the sows have more exercise, more control over their environment, more opportunity for normal social interactions and better potential for the provision of opportunities to root or manipulate materials. The major problems evident in good examples of tether-housing are also evident in stall-housing. As a consequence, group-housed sows show less abnormality of bone and muscle development, much less abnormal behaviour, less likelihood of extreme physiological responses, less of the urinary tract infections associated with inactivity, and better cardiovascular fitness. The major disadvantages for sow welfare of housing them in stalls are indicated by high levels of stereotypies, of unresolved aggression and of inactivity associated with unresponsiveness, weaker bones and muscles and the clinical conditions mentioned above. Some serious welfare problems for sows persist even in the best stall-housing system.

73. Recommendation: Since overall welfare appears to be better when sows are not confined throughout gestation, sows should preferably be kept in groups. However, only housing systems resulting in minimal aggression or injury should be used. This can be achieved in a housing system meeting the following criteria: sows in groups should be fed using a system which ensures that each individual can obtain sufficient food without being attacked, even when competitors for the food are present. All sows should have access to soil for rooting or manipulable material such as straw. Housing facilities for dry sows and gilts should include communal lying areas, in addition to any feeding stalls or boxes, of at least 1.3 m^2 per sow (0.95 m^2 for gilts). Opportunities for escape and avoidance, such as can be provided by generous space or well designed partitions, should be available for sows, especially those newly introduced to a group. Systems such as this, which are working well in common practice, are available. Individuals which are sick or injured, or which have been attacked by other sows, may temporarily be kept in individual pens. No individual pen should be used which does not allow the sow to turn around easily.

74. The manag ement of sows in groups requires careful monitoring of animals, good housing design and good stockmanship.

75. Recommendation: For all systems, groups should be kept as stable as possible, sows being returned to the same group after farrowing and new animals being introduced in small groups, e.g. 5. A facility for separating sick or injured animals from the group should be available.

76. The average piglet mortality in pig breeding is unacceptably high and measures should be encouraged to reduce this mortality without adversely affecting sow welfare.

77. Farrowing crates have both advantages and disadvantages from a welfare point of view. The advantages of farrowing crates over loose housing systems are: reduced piglet mortality caused by crushing; easier management including better farrowing surveillance possibilities; easier health control (including early detection of anomalies) and, in case of disease, easier treatment of the periparturient sow. The disadvantages of the farrowing crate over loose housing systems are: reduced possibilities for the sow to perform nest building behaviour; signs of increased stress before parturition; some studies indicate a decreased risk for MMA in the periparturient sow when kept loose.

78. Farrowing crates restrict the movements of the sow and usually sows are not given straw when in crates. It is not yet elucidated which of these factors, confinement and lack of straw, contribute most to those negative welfare aspects of the farrowing crate which were mentioned in the previous conclusion.

79. The extent to which welfare is reduced by keeping sows in farrowing crates for the whole lactation needs to be further elucidated; such effects have been suggested by certain studies.

80. Recommendation: The further development of farrowing systems in which the sow can be kept loose and carry out normal nest building, without the systems compromising piglet survival, should be strongly encouraged.

81. So-called segregated early weaning may have welfare advantages by decreasing the risks of infection of the piglets, but may cause reproductive problems in the sows. The welfare advantages may, to an unknown extent, be attributable to the practice of moving the piglets to another rearing site. However, other welfare aspects of the process, for example the behavioural and physiological responses of both sows and piglets, have not been studied.

82. Weaning is associated with increased risks of welfare problems, identifiable as abnormal behaviour, increased disease incidence, increased mortality and impairment of growth. These problems become more severe the younger the piglets are at weaning, but can be met by appropriate housing and husbandry routines for the newly weaned piglet.

83. Recommendation: The average weaning age should not be less than 28 days. However, for practical reasons associated with the health benefits of all-in all-out management, piglets may be weaned up to 7 days earlier. Individual piglets may occasionally be weaned earlier for medical reasons, for example if the sow ceases to lactate, becomes diseased or dies.

84. Recommendation: So-called segregated early weaning (weaning the piglets at 10-14 days and separating them from the maternal environment) should be allowed only if it is demonstrated that any welfare advantages to sows and piglets outweigh the disadvantages. In this respect, any advantage of multi-site rearing or of moving to new sites should be clearly distinguished from the effects of early weaning. Welfare assessment should take account of signs of poor welfare, such as mortality, diarrhoea, growth rate and behavioural indicators such as belly-nosing by piglets that maternal deprivation is causing problems to the piglets.

85. Behaviour, health and productivity of growing and finishing pigs are greatly influenced by the specific design of housing equipment, climatic factors and stockmanship.

86. Tail-biting, abnormal levels of aggression and other behavioural disturbances are more likely among fattening pigs when kept in barren environments.

87. Recommendation: Housing systems for growing and finishing pigs should facilitate separation of functional areas (feeding, resting and dunging area), or prevent direct contact with faeces in the resting area. They should account for the needs of pigs to investigate and manipulate materials and minimize competition.

88. Recommendation: Pigs that develop destructive behaviours should be removed from the group. Housing conditions in which a high prevalence of destructive behaviour occur should be adequately modified which may include one or a combination of the following measures: adequate light and climate, a sufficient and well balanced diet, cleanness of flooring and equipment, sufficient space, and features providing for occupational activities (bedding material, chains, etc.).

Socio-economic aspects

89. Some measures and housing systems whose aim is to improve animal welfare, increase the cost price of pigmeat and hence reduce farmers' income, whilst other measures have no cost or are even cost beneficial. However even very small increases in cost price can decrease income considerably. In the model examined a n increase in cost price of 1% decreases income by 30 to 50%.

90. The cheapest form of group housing for pregnant sows is cheaper from a per-sow investment point of view than the commonest individual housing system. However, this benefit would be outweighed by relatively small production differences, e.g. a 0.1 decrease in number of liveborn piglets per litter or a 3-4% increase in the annual culling rate of the sows.

91. Provision of straw for sows and fattening pigs, increased weaning age of piglets and increased space for sows and pigs are all relatively expensive ways to improve animal welfare. Providing more illumination is relatively cheap, and concrete floors instead of slatted ones is intermediate in this respect. In countries where labour and straw are relatively cheap, as is the case in the UK, the economic ranking of the measures may be different.

92. Most consumers are unlikely to be willing to pay more for pigmeat that is produced under conditions which they perceive to be better with respect to animal welfare. Therefore, there will be a serious threat to income and employment in the EU pig industry, due to a decline in competitiveness with respect to export on the world market on the one hand and the possible import of pigmeat from third countries where animal welfare standards are lower on the other. Restrictions on such imports may cause the EU difficulties because of GATT/WTO agreements. An example of such a threat is the US, although their cost price is already much lower in any case.

93. If consumers are not willing to pay for better animal welfare when imports from third countries where animal welfare standards are lower cannot be restricted, then the pig industry has no choice but to try to counterbalance the increase in costs, for example by increasing the herd size and improving economic efficiency.

94. The possibility that consumers will cease to buy pig meat if the welfare of pigs is perceived to be unacceptably poor should be considered although data concerning this point are not available at present.

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