Review

A review of environmental enrichment for pigs housed in intensive housing systems

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ABSTRACT

This paper critically reviews the literature concerning environmental enrichment for weaner, grower and finisher pigs housed in intensive (indoor) production systems. The thesis of our review is that successful enrichment should meet four criteria of success: (1) it should increase species-specific behaviour, (2) it should maintain or improve levels of health, (3) it should improve the economics of the production system, and (4) it should be practical to employ. We review the existing literature for three distinct classes of production systems; alternative enriched systems; straw-based systems, and barren systems enriched only with objects (‘point-source enrichment-objects’). Within each of these systems, we consider the effects of environmental enrichment on behaviour; health and physiology; animal performance, carcass quality and meat quality. We conclude that straw has the highest potential to meet the four successful enrichment criteria that we propose. However, we concede that it is possible to design successful point-source enrichment-objects if the wealth of knowledge available on enrichment for pigs is exploited. We also identify several knowledge gaps, especially in the area of the neurobiological effects of enrichment, which should be the focus of future research to advance the welfare of intensively reared pigs.

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1. Introduction

In modern systems of animal production, pigs are often confined within simple, invariant, housing systems that offer little potential to accommodate their highly motivated species-specific behaviours. The thwarting of motivated behaviour can result in psychological distress and is associated with the manifestation of abnormal behaviours such as stereotypies and passiveness (Wood-Gush et al., 1983; Spinelli and Markowitz, 1985; Chamove, 1989; Wemelsfelder, 1990; Poole, 1992).

The well-being of captive animals is not only dependent on the absence of pain, distress and behavioural abnormalities, but also on the extent to which simplified housing environments compromise physiological and ethological needs (Markowitz and Line, 1990). If the sacrifice required by the animal becomes too great, it loses its ability to cope, and this directly increases stress and reduces welfare (Broom and Johnson, 1993; Wiepkema and Koolhaas, 1993). Poole (1992) argues that the most suitable housing environments are ones where an animal is able to acquire experience which enables it to collect information and
analyse it, to build up a cognitive picture of the world in which it lives and to act on this knowledge'. We believe that 'acting upon this knowledge' refers to the ability of animals to cope within their captive environment and that this, ultimately, determines their welfare status.

Environmental enrichment is the modification of a barren captive-environment to improve the biological functioning of animals (Newberry, 1995). Enriched environments enhance the well-being of animals by allowing them to perform more of their species-specific behavioural repertoire and accommodate a larger range of behavioural choices. The term environmental enrichment is used widely in the literature but, from a scientific point of view, it should only be applied to situations where environmental modifications have enhanced the performance of strongly motivated species-specific behaviours or have led to the expression of a more complex behavioural repertoire (Poole, 1992; Newberry, 1995).

The scientific examination of environmental enrichment began to gain popularity in the 1960s. These early studies examined the effects of enrichment on learning ability and brain plasticity (for an overview, see Renner and Rosenzweig, 1987). In the 1970s, zoos began to employ enrichment programmes to enhance the expression of naturalistic behaviour and to reduce the incidence of behavioural problems in captive animals (Shepherdson, 1998). As the science of environmental enrichment matured, the objective of the research shifted towards improving animal welfare in a variety of other situations such as in laboratories or on farms (Chamove, 1989; Mench, 1994; Markowitz and Gavazzi, 1995) and more recently, for pets in the home (Milgram et al., 2006).

The welfare of pigs housed in intensive production systems is often viewed as being compromised and this has led to a large volume of research examining the potential for environmental enrichment to improve conditions. In contrast to the environments in which the pig has evolved, intensive production systems are often very barren with concrete (slatted) floors and no substrate in which the animals can root. Such environments thwart the expression of key behaviours such as exploration and foraging, which are highly motivated behavioural systems in the pigs. As a consequence, harmful, manipulative, social behaviours such as ear and tail-biting often occur at high frequencies (e.g. Fraser et al., 1991). Successful enrichment should decrease the incidence of abnormal patterns of behaviour and increase the performance of behaviours such as exploration, foraging, play, and social interaction, which are within the range of the animal's, normal, species-specific behaviour (Chamove, 1989; Mench, 1994; Markowitz and Gavazzi, 1995; Van de Weerd and Baumanns, 1995).

Since January 2003, the provision of appropriate environmental enrichment to pigs of all ages has been mandatory across the European Union (EU) (Directives 2001/88/EC and 2001/93/EC). The Directives state that: 'To enable proper investigation and manipulation activities, all pigs must have permanent access to a sufficient quantity of material such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such which does not adversely affect the health of the animals'. The substrates listed are clear examples of different types of enrichment. However, sometimes these substrates cannot be given and, if alternatives need to be provided, there is room for debate about which other materials should be used. Furthermore, it might not be intuitively clear how to interpret 'proper investigation and manipulation'. Therefore, within the EU, the current legislation governing pig enrichment offers guidance but leaves room for interpretation.

Within the pig-production industry a trade-off exists between the needs of the animals and that of the farming system in which they are reared. Producers have both economic and practical constraints on the extent to which they can offer environmental enrichment to their animals. For example, the provision of the particulate substrates described in the EU Directives 2001/88/EC and 2001/93/EC are very difficult to offer in systems with partly or fully slatted flooring as they would block the liquid-slurry handling-system. Therefore, enrichment needs to be practical otherwise its implementation will be hampered (Van de Weerd and Baumanns, 1995).

The effects of environmental enrichment can be examined from a number of different angles. Behaviour, physiology and neurology all offer insights into how enrichment actually improves animal welfare (Broom and Johnson, 1993; Young, 2003). Enrichment studies for farm animals often focus on behavioural outcomes, but it is equally important to evaluate other aspects such as the effects on physiology and health. For example, enrichment that is used by animals but that has a detrimental effect on their health should be regarded as unsuitable. In addition, within animal production systems, the economic implications of enrichment strategies are also important to consider. If enrichment affects factors such as animal performance (e.g. feed conversion efficiency and carcass quality) or meat quality, this may hamper its adoption on a commercial scale. However, there is also an increased public demand for meat originating from welfare-friendly systems with the expectation that meat from such systems has a better quality (Peeters et al., 2006). If a premium would be paid by consumers for such products, the costs of enrichment could be absorbed.

It has been argued that it is important to have intimate knowledge of the specific behaviour of a species when designing enrichment (Young, 2003). However, it is often not possible to use the behaviour of the animal in the wild as a benchmark because a lot of this natural behaviour is not documented and may be highly variable and dependent on local environmental conditions (Mench, 1994; Newberry, 1995; Shepherdson, 1998). Therefore, a more workable approach is to specify target behaviour that is functional and adaptive in specific environments rather than ‘natural’. Enhancing this target behaviour then becomes the objective of the enrichment programme (Newberry, 1995; Van de Weerd and Baumanns, 1995; Veasey et al., 1996; Van de Weerd et al., 2003).

1.1. Aim of the review

The aim of this review is to offer a critical overview of the existing literature concerning enrichment for pigs in intensive (indoor) production systems with the objective
of defining what is, or is not, successful enrichment. Our thesis is that successful enrichment should meet four criteria of success: (1) it should increase species-specific behaviour, (2) it should maintain or improve levels of health, (3) it should improve the economics of the production system, and (4) it should be practical to employ.

2. Structure of the review

A variety of pig-housing systems are detailed in the literature concerning environmental enrichment. As the potential for environmental enrichment is inversely proportional to the complexity of the environment, our review distinguishes three different levels of enrichment (1) alternative enriched-housing-systems, (2) systems enriched with a straw bed and (3) systems enriched with objects only. Previous studies have reviewed the literature concerning straw only (Arey, 1993; Tuyttens, 2005), or have focussed mainly on enrichment objects (Bracke et al., 2006).

2.1. Alternative enriched-housing-systems

Alternative enriched-housing-systems are ones that differ radically from conventional production systems and that have been designed to meet the key behavioural needs of pigs (e.g. Stolba and Wood-Gush, 1984; Simonsen, 1990; Beattie et al., 1995). This approach was pioneered by Stolba and Wood-Gush (1984) who released pigs into a large, natural, enclosure (‘The Edinburgh Pig Park’) and catalogued the key behaviours that were expressed. They also identified the environmental features that appeared to be of importance to the pigs and then incorporated these features into a simplified, manageable, enriched housing system which was named ‘The Family Pen System’.

The Family Pen System was tested subsequently on commercial farms (e.g. Wechsler, 1996) and it was demonstrated that the system was both practical to run, and the reproductive performance of sows could reach levels comparable to conventional housing systems. There is general agreement that the ‘Family Pen System’ offers pigs a physical environment of high quality (Wechsler, 1996).

2.2. Straw-based housing-systems

Straw-based housing-systems are common in geographic areas where straw is in plentiful supply. Such systems offer a viable alternative to housing with fully or partly slatted flooring, artificial ventilation, and liquid-slurry handling. Straw is generally regarded as a valuable, functional, form of enrichment for pigs (e.g. Tuyttens, 2005). It has been commented that by understanding the specific motivational salience of straw, it could be possible to design functional enrichment for pigs housed in slatted systems (Van de Weerd et al., 2003). There is a large body of literature concerning the general advantages of straw-based systems in relation to pig welfare, and these have already been comprehensively reviewed (Arey, 1993; Tuyttens, 2005). Therefore, in this review, we only include studies that advance our understanding of why straw is such an effective enrichment for pigs.

2.3. Housing systems with point-source enrichment-objects

Point-source enrichment-objects are the objects most people probably associate with enrichment, and these are often referred to as ‘toys’. As enrichment objects are generally limited in size, and their use is often restricted to a single location in a pen, the term ‘point-source enrichment-objects’ will be used in this review to refer to this type of enrichment device.

Within each of the three levels of enrichment covered, the review will consider the evidence for effects on: (1) behaviour, (2) health and physiology, (3) performance and carcass quality and (4) meat quality. The review does not include pregnant sows and breeding boars because the focus of most of the enrichment literature is the weaner, grower and finisher pig. Studies investigating enrichment for sows are very scarce, and most research efforts have concentrated on studying pre-partum nest building in sows and the use of nesting material (e.g. Widowski and Curtis, 1990; Arey, 1993). Enrichment for breeding boars has received hardly any attention from the scientific community. These animals are often, but not always, kept in straw-bedded pens and they are mostly housed individually. As the enrichment legislation in force in the EU covers all pigs, these animals also require some form of enrichment if straw cannot be provided. Work is required in this area to assist producers in choosing appropriate enrichment strategies for their breeding animals.

3. Alternative enriched-housing-systems

3.1. Behaviour

3.1.1. Home pen behaviour

Beattie et al. (1995) studied an alternative enriched-housing-system for pigs that was segmented into five main areas; a rooting area containing peat, a bedded area with straw and a straw hopper, a sleeping area with an enclosed kennel containing shredded paper and a fully slatted area with drinkers and feeders. The pigs in this system were also housed at a lower stocking density than typically used in conventional intensive systems.

The behaviour of pigs in this alternative enriched system was studied in a series of experiments (Beattie et al., 1995, 1996, 2000a,b). The size and design of the pens were similar throughout, as were the behavioural observation techniques used. When the behavioural time-budgets in the alternative enriched-housing-system were compared with a barren control group, differences in the levels of exploration, aggression and harmful social behaviour were detected. Pigs from enriched pens spent up to 25% of the observed time interacting with the enrichment substrates, whereas pigs in barren systems channelled their activity towards the pen fixtures. In addition, pigs in the enriched environment spent less time ‘inactive while alert’ and expressed less ‘harmful social behaviour’ and ‘aggressive’ behaviour (such as head thrusting) than pigs
housed in the barren control pens. In particular, the levels of ‘nosing pen-mates’, ‘ear-, tail- or leg-biting’ were reduced. In these studies, pigs housed in the alternative enriched-housing-systems were provided with up to four times as much floor space as the pigs housed in the barren pens. Therefore the effects of space and enrichment were confounded. Beattie et al. (1996) attempted to address this concern and concluded that the enrichment in the system played a greater role in determining pig behaviour than available floor space.

Fraser et al. (1986) developed a two-level pen containing a raised rectangular-platform and compared the behaviour of grower/finisher pigs with conventional partly slatted barren pens. Although Fraser’s pen seemed to just differ in structure from conventional pen designs, the two-level pen offered greater environmental diversity, including extra space, a hiding area (under the ramp), and different microenvironments on the upper and lower levels. There were good levels of hygiene on the upper level because it remained unsoiled by the pigs. It was also found that the pigs chose different lying areas in response to variations in the climatic conditions. Fraser et al. (1986) concluded that the two-tiered design offered distinct welfare advantages as it provided pigs with behavioural choices and thus greater levels of control over their environment.

Pedersen et al. (1993) extended Fraser’s work by developing a new alternative enriched-housing-system. This system included a mezzanine tier, accessible via a ramp, manipulanda (a wheelbarrow wheel with concrete on a metal frame, a steel ring attached to a concrete filled wheel and a triangular, suspended mobile with rubber hoses) and a hiding area. They compared the pig’s behaviour in the alternative system with control pens that did not have any modifications (standard pens with partly slatted floors). No major effects of system design were detected in home pen behaviour, but higher levels of aggression were recorded among pigs in the enriched pens. These pigs were more reluctant to use the feeders located on the mezzanine floor, and this may have resulted in less feeder space per pig in the enriched pens, and thus more competition over feed.

Simonsen (1990) studied the behaviour of pigs in a multi-activity pen, segmented into three main sections that offered the opportunity to interact with either straw bedding, a pig-operated shower, straw racks and logs hung on chains. Although no behavioural comparisons were made with pigs housed in control pens, the pigs in the multi-activity pen were found to use all the different pen areas offered. The behaviours ‘sniffing pen mate’, ‘aggression’ and ‘non-aggressive biting’ occurred at different levels in the functional areas of the environment; suggesting segmentation of behaviour. Most ‘resting’ occurred in the straw and feeder section, and the pigs were found to keep the resting areas free from excreta. They made good use of the straw racks, logs and shower. ‘Tail-in-mouth’ behaviour was rarely observed, and ‘aggression’ was low, however, such behaviours were affected by the number of pigs housed in the system (Simonsen, 1990). Lund and Simonsen (1995) conducted a similar study to investigate the separate and interactive effects of housing system and genotype. The alternative enriched system consisted of straw offered in a rack, logs suspended on chains and a 12 kg stone. Pigs of two breeds became less ‘aggressive’ and more ‘active’ during the 3-month study period. Object-directed activities increased significantly over time for Danish Landrace gilts, but not for Duroc gilts. The authors concluded that the provision of logs may be an easy and cheap way to enrich an environment.

It should be noted that the studies mentioned in this section do not always include control groups (i.e. non-enriched systems), which makes it difficult to assess the overall impact of the enrichment. In some cases, environmental enrichment and stocking density are totally confounded which makes it impossible to discriminate between the effects of enrichment and the effects of increased space allowance. For example, stocking density is known to be an important risk factor for tail-biting (Moinard et al., 2003).

3.1.2. Novel object test

When an unfamiliar object is introduced into the home pens of pigs, their behavioural response can be influenced by the type of environment in which they are housed. This phenomenon was demonstrated by Stolba and Wood-Gush (1980) who presented an unfamiliar object (tyre) to pigs in a semi-natural, wooded, enclosure. These pigs reacted less strongly towards the tyre in comparison to pigs from three other, more intensive, systems. With increasing barrenness of the environment, the reaction to novelty became stronger and a greater proportion of the animals in the group interacted with the object and the sessions lasted longer. This suggests a strong level of exploratory motivation in pigs reared in barren environments (see also Section 3.1.6).

3.1.3. Novel environment test

Pigs from the alternative enriched-housing-system of Beattie et al. (2000a) were found to be more responsive in a novel-pen test. They showed significantly more locomotor behaviour, vocalised more frequently, were quicker to contact a novel object, and spent longer in contact a novel object than their counterparts housed in barren environments. Pigs from enriched systems appear to be less inhibited by fear and have an enhanced ability to adapt to novelty. Sneddon et al. (2000) subjected growing pigs to an operant task and maze test that required spatial learning. It was found that the pigs from the enriched environments learned both tasks significantly more rapidly and showed greater stability of learning by making fewer errors; suggesting that the cognitive development of pigs from barren systems may be impaired.

3.1.4. Handling

There has only been one study that has investigated whether housing pigs in alternative enriched-housing-systems influences their ease of handling and reaction to novel situations (Pedersen et al., 1993). Pigs housed in the enriched pens that incorporated a mezzanine tier and different manipulanda were significantly easier to handle when driven into a raceway and onto weighing scales. They
were also less fearful as fewer animals required 'tapping' or 'prodding' before entering the raceway and scales.

3.1.5. Aggression

When pigs were reared in the alternative enriched-housing-system of Beattie and co-workers, a reduction in aggression was observed in comparison with barren control-pens (O’Connell and Beattie, 1999). Piglets were tested (weekly) in a social confrontation test, during which they were mixed with unfamiliar animals in a wooden test-box. Piglets from the enriched environments showed significantly less aggressive behaviour than pigs from the barren control-pens and this effect increased over time. When the same pigs were tested at 12 weeks of age in a food competition test, no direct differences in dominance were detected. The authors suggest that dominance characteristics are established early in life and remain stable throughout the growing period.

3.1.6. Behavioural diversity

A series of studies has investigated whether the behavioural diversity of pigs is increased by being housed in highly enriched pens (straw, forest bark and branches) in comparison with being housed in barren pens (Haskell et al., 1996; Mendl et al., 1997; Wemelsfelder et al., 2000). Haskell et al. (1996) found that individual pigs housed in enriched pens had a significantly higher relative diversity of behaviour when manipulating their home environment compared with pigs in the barren pens. Relative diversity was defined as the number of behavioural elements observed expressed as a proportion of the total number of elements possible in a certain environment. It was concluded that the reduced relative behavioural diversity of pigs housed in barren pens may have either reflected a low motivation to interact with and manipulate unsuitable substrates, or a more pervasive shift in the organisation of behaviour.

In an extension of this work, Wemelsfelder et al. (2000) investigated whether the reduced behavioural diversity of pigs from barren environments was specific to the home pen environment. Pigs from both types of pens were tested in a voluntary novel-object exploration-test either in their home pen or in a novel arena. Again, the pigs from the barren environments showed less diverse behaviour, meaning that they used fewer behavioural elements in their interactions with novel objects. This suggests that barren housing conditions may affect structurally the organisation of behaviour in growing pigs. The behaviour of pigs from the enriched environments was characterised by mobility, variety and excitement, whereas pigs from the barren pens focused on particular substrates.

Mendl et al. (1997) subjected 5-month-old pigs from highly enriched and barren pens to a series of T-maze, spatial discrimination, trials using a food reward as an incentive. Pigs from the barren environment did not show the expected fixed, unvarying, response to these tasks, but they spent more time investigating the maze, while pigs from the enriched environments moved fairly rapidly to the food. This suggests that ‘forced exploration’ in tests like an open-field or a maze may be motivationally different to the behaviour that an animal shows in a situation where it has freely chosen to interact with novel stimuli (cf. Welker, 1957). The elevated levels of investigative behaviour in the novel maze by pigs from barren environments is in agreement with findings from other studies (Stolba and Wood-Gush, 1980; Wood-Gush et al., 1990) and possibly reflects a ‘rebound’ in response to the lack of opportunities to express exploration in impoverished home environments.

3.2. Health and physiology

Pigs from the enriched alternative-housing-system designed by Beattie et al. (2000a) exhibited higher average and maximum heart rates when they were moved to a novel-object test-arena than pigs from control pens. These pigs also had higher maximum heart rates during the first minute of a novel-object test. The higher heart rates were most likely related to the higher behavioural activity levels in the novel object test, however, this was not controlled for. The authors suggest that these pigs had more reactive sympathetic-nervous-systems than their barren housed counterparts, because they also had a greater number of lesions in the endothelium of the heart. At slaughter, plasma cortisol levels in pigs from the enriched alternative systems were higher and there was some indication of an elevated cortisol response in the novel object test, although this did not differ significantly from pigs reared in barren pens. Pigs from the barren pens had greater adrenal weights at slaughter suggesting chronic activation of the pituitary-adrenal axis and a suppression of cortisol responses to acute stress.

Pedersen et al. (1993) monitored the health of pigs in their alternative enriched-housing-system throughout the trial. At the beginning of the trial, there were no differences in injury scores on different body parts, but towards the middle and end of the trial, higher injury scores were found on pigs housed in enriched pens. In the enriched housing system, pigs were more reluctant to use the feeders located on the mezzanine floor. This may have resulted in less usable feeder-space per pig on the ground floor and led to more competition and fighting over feed. Immuno-physiological measures (cell-mediated immune response) and neutrophil:lymphocyte ratios (N/L ratios) were not affected by housing treatment. Basal plasma cortisol concentration and hypophysio-adrenocortical function with ACTH challenge also yielded no major differences between the treatments.

Fraser et al. (1986) reported that the level of injuries, tail-biting and lameness in the two-level pen were better than pigs housed in conventional pens. They speculated that this could be due to the increased opportunities for physical exercise and the provision of hiding places. Vermeij et al. (2003) tested a similar pen design with two levels and found positive results. The majority of the pigs used the upper level and there were no signs that the pen design influenced the health of the pigs.

3.3. Performance and carcass quality

The performance of pigs in the alternative enriched-housing-system of Beattie and co-workers has been
described in several papers (Beattie et al., 1995; Beattie et al., 1996; O’Connell and Beattie, 1999; Beattie et al., 2000b). Although housing systems of a very similar design were used, the studies found quite different effects on performance. Beattie et al. (1995) and O’Connell and Beattie (1999) found effects of housing on performance parameters (body weight, daily growth, feed intake or feed conversion ratio, FCR). In another study, pigs from the enriched environment had higher growth rates due to higher feed intakes, a better FCR in the finishing phase, heavier carcasses, and higher levels of back-fat than their counterparts from barren environments (Beattie et al., 2000b). Beattie et al. (1996) found that performance was improved by offering enrichment in their alternative system. Factors that may have influenced these findings include differences in management and potential differences in behaviour such as harmful social behaviour, aggression (see Section 3.1.1), and/or stress levels. Pedersen et al. (1993) reported that weight gain and FCR did not differ significantly between pigs housed in the alternative enriched housing system (with hiding areas, a mezzanine tier and manipulanda) and housed in barren control-pens. Daily food intake was significantly higher in pigs from barren pens, however, this effect was attributed to wastage of feed as these pigs used the feeder as a play object.

The performance of the grower pigs in the two-tiered pen developed by Fraser et al. (1986) was similar to that measured in the control pens, except for the first week of introducing the pigs to the new system. The performance during this week was poorer; possibly reflecting that some pigs took time to learn to use the ramp and find the feeder located on the top floor.

3.4. Meat quality

Meat quality was also studied in the alternative enriched-housing-system evaluated by Beattie and co-workers. Pigs from the enriched housing conditions produced pork that was more tender (lower shear force values) and had lower cooking losses than pigs reared under barren housing conditions (Beattie et al., 2000b). These improvements in meat quality were not associated with differences in pre-slaughter stress because pH values were similar across both treatments. Therefore, the effect was more likely caused by elevated levels of back-fat, which were higher in the pigs reared in the enriched system. Different effects were found in another study by the same research group (Beattie et al., 1993). Pigs which spent the final weeks of their life in the alternative enriched-housing-system were found to have a less tender Longissimus Dorsi muscle, with associated pH and fat levels not differing significantly from controls. The authors suggest that the effects could have been caused by differences in levels of exercise between the systems. However, this does not seem likely as the effect of exercise on meat quality has been investigated by Gentry et al. (2002b) who found no effects of increased exercise on meat quality variables.

4. Straw-based housing-systems

4.1. Behaviour

4.1.1. Main benefits of straw

Straw has been accepted as a valuable source of enrichment for pigs for many years. It is known to be valued by pigs because it (1) improves the thermal and physical comfort of the floor when used as bedding, (2) provides bulky gut fill when ingested by feeding motivated pigs, and (3) serves a recreational function and acts as a stimulus and outlet for rooting and chewing activities (Fraser, 1975, 1985; Fraser et al., 1991). However, despite such strong benefits, the use of straw is not applicable in many situations. For example, in systems that incorporate fully or partly slatted flooring, the use of particulate substrates in significant quantities would block the liquid-slurry handling-facilities.

As was outlined in the introductory section of this review, our objective is not to repeat the work conducted by other reviewers of straw-based systems in the past (e.g. Arey, 1993; Tuyttens, 2005). We will, therefore, concentrate on the properties of straw that are beneficial to pigs with a view to exploiting this knowledge to develop alternative strategies that are compatible with modern housing and manure handling (Fraser, 1985; Arey, 1993).

Fraser (1985) presented straw to pigs in three ways: (1) chopped straw mixed with food, (2) a small amount in the food trough, or (3) a large amount of straw. This approach allowed the dietary, recreational and bedding benefits of straw to be investigated separately. To study the bedding benefits in more detail, Fraser offered bedded and unbedded pen areas to weaner pigs under different environmental temperatures (Fraser, 1985). When the temperature was within the thermo-neutral zone, the use of straw for recreation became more prevalent and the focus of rooting and chewing behaviours.

Fraser et al. (1991) studied the recreational benefits of straw in ad libitum fed growing pigs to minimise the level of feeding motivation and the likelihood of straw consumption. When the pigs were housed at a comfortable temperature straw was found to act as an outlet for explorative and manipulative activities involving the snout and the mouth (rooting and chewing). In addition, these activities tended not to be directed at pen-mates. The provision of straw bedding has been frequently linked with lower incidences of undesirable pig-directed behaviours including tail-biting (Ruiterkamp, 1987; Schouten, 1987; Lyons et al., 1995; De Jong et al., 1998; Kelly et al., 2000; Guy et al., 2002a; Van de Weerd et al., 2005; Scott et al., 2006a; Day et al., 2008).

When straw is provided as bedding, it covers the whole floor area. Inevitably, this increases the proportion of time that pigs can spend manipulating the substrate, and results in higher levels of activity (McKinnon et al., 1989; Arey and Franklin, 1995; Lyons et al., 1995; Morgan et al., 1998; Kelly et al., 2000; Guy et al., 2002a; Van de Weerd et al., 2006; Scott et al., 2006a; Day et al., 2008). When pigs are offered a full bed of particulate substrates such as straw, they spend about 25% of the active time interacting with it (Beattie et al., 2000a,b).
When straw enrichment is compared with point-source enrichment-objects, studies report up to twenty times as much interaction with the straw in comparison with the objects (Ruiterkamp, 1987; Lyons et al., 1995; De Jong et al., 1998; Scott et al., 2006b, 2007; Van de Weerd et al., 2006). The presence of straw in combination with objects appears not to influence the levels of straw directed behaviour. Examples of objects tested in combination with straw include metal chains, a dried cow’s tendon, a car tyre, a sterilised cow bone (Heizmann et al., 1988), a hanging plastic-object with chewable sticks (Bite-Rite, Ikadan System, Denmark, in Scott et al., 2006b) and a cross-shaped device made of alkathane piping (Scott et al., 2007).

A study by Van de Weerd et al. (2006) showed that straw is not only manipulated by pigs while they are active, but also when they are lying down. The use of straw while lying was observed in 6.6% of the observations. The use of point-source enrichment-objects while lying was observed in only 1% of the observations. However, in commercial practice, the manipulation of point-source enrichment-objects from a lying position is often not possible (or, at best, only to a limited extent). When enrichment is restricted to a discrete area of the pen, the pigs direct a large part of their exploratory behaviour towards the (barren) pen floor. In a study by Petersen et al. (1995), the time spent rooting at the floor and walls in barren pens was almost ten times greater than the time spent rooting at substrates by pigs in enriched straw pens (with logs and branches). The high levels of rooting behaviour that are directed at very ‘unrootable’ substrates such as concrete flooring was argued by Van Putten (1980) to illustrate how important rooting is to pigs.

There are some indications that when pigs have limited or no environmental stimuli to direct their behaviour towards when lying down, they may start manipulating the tails of pen-mates. Significant behavioural transitions between pen-mate manipulation and lying inactive have been found (Petersen et al., 1995). This study revealed that the levels of ‘nudging’ and ‘tail-bitng’ were lower in straw-enriched pens than in barren control-pens. Animals have been frequently observed to be ‘inactive but awake’ in pens without enrichment or with minimal levels of enrichment (e.g. Pearce et al., 1989; Durrell et al., 1997).

4.1.2. Other aspects of straw

The quantity and quality of straw-directed behaviours is affected by the length of straw provided. Day et al. (2008) offered growing pigs access to straw that was chopped, half chopped or full-length. It was found that chopped straw increased the prevalence of behaviours such as ‘licking’ and decreased the prevalence of behaviours such as ‘picking’, suggesting that pigs are not able to manipulate chopped straw in the same way as full-length or half chopped straw. In addition, chopped straw was found to elevate levels of ‘tail-bitng’ in comparison with groups with full-length or half chopped straw. Activity levels were also affected, with pigs being more active when provided with full-length straw than when provided with half-chopped or chopped straw.

It is also known that prior experience of straw can affect behaviour in later life (Day et al., 2002a). Pigs with prior experience with straw bit tails of other pigs more in an environment where straw was not provided compared with pigs that had had no prior experience of straw.

As would be expected, the amount of straw-directed behaviour is proportional to the quantity of straw provided. However, increasing amounts of straw appear not to greatly affect the diversity of straw-directed behaviour (Kelly et al., 2000; Day et al., 2002a). Day et al. (2002a) reported that ‘rooting’ and ‘ploughing’ of straw increased in proportion to the amount to straw provided, while the expression of ‘aggression’ and ‘manipulating other pigs’ (belly nosing, tail-bitng, ear chewing, licking, biting and nosing) showed an inverse relationship (Day et al., 2002a). This adds weight to the theory that straw serves as an outlet for exploratory and manipulation activities (Fraser et al., 1991).

It has been argued that straw or any other substrate should be replenished regularly with fresh material because this may increase levels of novelty (Heizmann et al., 1988; Moinard et al., 2003).

4.1.3. Novel environment test

It is known that enrichment modifies exploratory behaviour (see Sections 3.1.6 and 5.1.1.). However, De Jong et al. (2000a) found that housing pigs in large straw-bedded pens throughout their life did not influence their exploratory behaviour in a novel environment (the passageway adjacent to their home pens) when this was compared with the exploratory behaviour of pigs housed in partly slatted barren-pens. This is in contrast with expectations, but may be explained by the use of different methodologies to measure exploration.

De Jong et al. (2002a) also examined the effects of enrichment on long- and short-term memory. The barren-housed pigs showed signs of impaired long-term spatial memory in a maze test because they made more mistakes than the pigs housed in the straw-bedded pens. However, the pigs from the two treatments did not show differences in learning abilities (short-term memory) during training sessions on different versions of the maze.

The behaviour of pigs in a novel lairage-pen has been found to differ depending upon whether they originated from strawed or barren pens (Geverink et al., 1999). The pigs from strawed pens showed significantly more exploratory behaviours such as ‘sniffing’, ‘biting’, ‘rooting’ and ‘chewing’. The authors discussed these results in relation to the amount of stress involved in loading, transport and unloading in a novel environment. They concluded that the pigs from the straw pens were less affected by these procedures. These findings suggest that the experience of straw can influence exploratory behaviour in a novel environment.

4.1.4. Handling

The effect of straw on the ease of handling pigs has hardly been investigated. Geverink et al. (1999) found that stockmen needed more time (half a minute per group) to move pigs from large straw-bedded pens into a transport box than they needed to move pigs from barren pens. However, these results may have been influenced by the pigs being moved out of their pens at different ages for
other measurements (for the study by De Jong et al., 1998). When pigs from straw-bedded or barren housing systems were isolated for 1 h to impose an acute stressor, there were no differences in behaviour or vocalisations. However, when the pigs were restrained with a snare, those housed in the strawed system squealed significantly more (De Jong et al., 1998).

4.1.5. Aggression

Several studies have failed to demonstrate differences in aggression between pigs from strawed and barren systems (Fraser et al., 1991; Lyons et al., 1995; Petersen et al., 1995; Guy et al., 2002a). Other studies have found that straw bedding also appears not to reduce fighting between newly mixed growing-pigs (Arey and Franklin, 1995). In a confrontation test, the agonistic behaviour of pairs of pigs was also not influenced by different housing systems (strawed vs. unstrawed system) (De Jong et al., 1998). However, in contrast to these findings (Day et al., 2002a) found that pigs with access to straw showed lower levels of aggression than their counterparts which did not have access to straw. To further complicate any meta-analysis, Morgan et al. (1998) demonstrated an elevated prevalence of aggression in a straw-based treatment compared with a barren control. These different findings may be explained by the fact that not all studies corrected data for higher levels of activity of pigs in pens with straw which may have skewed the results. In addition, it could also be argued that the differences exist in the baseline aggressiveness of the pigs studied.

4.2. Health and physiology

4.2.1. Respiratory system

It has been suggested that straw bedding may have a negative impact on the health of pigs because it can harbour pathogens (such as bacteria, viruses or fungi) and increase the levels of dust in housing systems (Arey, 1993). However, the scientific evidence to support this is limited and contradictory. In a longitudinal research study (Scott et al., 2006a), the health and welfare of finishing pigs were monitored in two contrasting housing-systems (fully slatted vs. straw-bedded). Four consecutive studies were carried out over a three-year period, and included more than 4000 pigs. Veterinary intervention to maintain satisfactory levels of health was higher in the straw-based system, with respiratory conditions being the major reasons for treatment. However, the number of pigs removed from the study because of respiratory conditions did not differ between the housing conditions, nor did the measured levels of dust. Post-mortem lung lesion-scores were low and did not differ between the housing systems.

Gentry et al. (2002a) detected no differences in the total incidence of lung lesions between pigs housed in slatted pens or deep-straw-bedded pens. However, when the data were analysed in more detail, the level of severe lung-lesions was approximately double in the pigs from slatted-floor housing-systems. Guy et al., 2002c found that pigs from straw yards had lower average lung-damage due to enzootic pneumonia. He also found that straw yards had lower levels of total and settled dust, but similar levels of respirable dust and ammonia to partly slatted pens.

4.2.2. Feet

Another health-related variable that has often been investigated is foot injuries. Scott et al. (2006a) found that the number of pigs removed from her study due to lameness was higher in the fully slatted system than in the straw-based system. Post-mortem assessment of foot damage revealed significant differences in the type of injury due to the housing system. Pigs from the fully slatted system had more severe heel and sole erosions, whereas pigs from the straw-based system had significantly higher severity scores for toe erosions. These results are in accordance with the hypothesis that bedded floors reduce the pressure on the weight-bearing surface of the foot such as the heel and sole (Mouttotou et al., 1999).

Lyons et al. (1995) reported that the severity and prevalence of adventitious bursitis of the hock were significantly greater in housing systems that do not include straw (e.g. bare concrete and slatted pens vs. deep straw and straw flow system). At the end of the trial all pigs from slatted pens were affected by bursitis or de-hairing of the legs, and the rate of de-hairing was reduced in pigs from strawed pens. Gentry et al. (2002a) found that pigs housed on concrete slats had a higher overall incidence of foot pad and toe lesions (>50% of sampled pigs). Within the affected animals, foot lesions classified as being severe were more prevalent in the pigs originating from deep-bedded pens, probably caused by wet bedding. Pigs from partly slatted systems have been found to have higher final adventitious bursitis scores compared with pigs from straw yards (Guy et al., 2002c). This result is in accordance with findings from Scott et al. (2006a) who found higher bursitis scores (=more swelling) for pigs housed in fully slatted systems (scored weekly).

A study which examined the prevalence of foot lesions at an abattoir reported that 93.8% of the pigs monitored (sample size 3974) had some form of foot lesion (Mouttotou et al., 1999). The study showed that each type of flooring system (barren solid or bedded, partly or fully slatted) was associated with its own characteristic types of lesions. The risk of bursitis is reduced when the floor is either fully or partially covered with straw. However, dampness and poor hygiene may intensify the effect of flooring on the incidence of claw disorders. These results indicate that foot lesions are more common, but not necessarily more severe, in slatted systems.

4.2.3. Wounds

The number of external injuries or wounds counted at regular intervals is often used in studies as a measure of social unrest. Injury scores are generally found to be significantly lower in pigs that are housed in straw-based systems than pigs housed in systems without straw (Schouten, 1991; Lyons et al., 1995; Guy et al., 2002c). Scott et al. (2006a), on the other hand, did not find differences in skin lesions between pigs from fully slatted and straw-bedded systems. In addition, adding an enrichment object (a cross-shaped device of alkathane piping) to straw-bedded pens did not affect skin lesions (Scott et al., 2007).
4.2.4. Gastric ulceration

Gastric ulceration is sometimes measured as a stress indicator. A limited number of studies have reported that the incidence of gastric ulceration is higher in pigs from slatted systems than in pigs from strawed systems (Guy et al., 2002c; Scott et al., 2006a).

4.2.5. Body temperature and salivary cortisol

De Jong et al. (1998) studied the physiological effects of housing pigs throughout their life in straw-bedded pens or in smaller, partly slatted, barren pens. Pigs from both housing conditions exhibited similar reactions in body temperature and heart rate (measured using telemetry) in response to stressors such as relocation, isolation and restraint. However, there were differences in baseline values measured before the stressors were applied, where pigs from the barren environments had higher baseline body temperatures. The hypothalamo-pituitary-adrenal (HPA) axis was found to be differentially activated depending upon whether the pigs were housed in strawed pens or barren pens. Pigs from the strawed pens had significantly higher baseline salivary cortisol concentrations at 14 and 17 weeks of age. Cortisol in saliva is the free, biologically active, form and correlates well with levels of cortisol in the blood plasma. The effects found could have been caused by differences in the circadian release of cortisol between the groups of pigs. Subsequent studies investigating circadian patterns in cortisol (sample collection over 24 h) confirmed this finding (De Jong et al., 2000a). The authors concluded that barren-housed pigs have a blunted circadian rhythm in salivary cortisol and that their results suggest an ongoing state of chronic stress in barren housed pigs, which might be linked to a psychological state of depression (see also De Groot et al., 2000). The higher baseline body temperature in the barren-housed pigs (De Jong et al., 1998) is in agreement with this hypothesis. Other studies with a similar design and performed at the same institute also found higher baseline salivary cortisol levels in pigs from strawed pens (Geverink et al., 1999; De Jong et al., 2000b; Klont et al., 2001).

There is still a distinct lack of clarity as to whether the circadian rhythms of cortisol are influenced by levels of pig activity, because different levels of activity for straw and barren pens have been reported (home pens: De Jong et al., 1998; lairage: Geverink et al., 1999; Klont et al., 2001). A clearer picture of whether there is a relationship between activity and cortisol levels may emerge if circadian patterns of activity are investigated (De Jong et al., 2000a). Elevated levels of plasma cortisol have been found in pigs from alternative enriched-housing-systems (see Section 3.2) during a novel-environment test; possibly suggesting that enriched pigs have a more reactive sympathetic nervous system (as suggested by Beattie et al., 2000a), and that activity is not the main cause.

Pigs from barren housing-conditions have a significantly higher increase in cortisol levels in response to handling, transport and lairage than the pigs from strawed pens (Geverink et al., 1999; De Jong et al., 2000b; Klont et al., 2001), indicating that pigs housed in barren conditions experience more stress during pre-slaughter procedures (see also Section 4.1.3).

4.2.6. Immune functioning

De Groot et al. (2000) investigated whether the difference in baseline cortisol levels between pigs from partly slatted barren-pens or larger straw-bedded pens influenced immune functioning and, therefore, maybe, resistance to disease. Only slight differences in the investigated parameters of immunity (leucocyte and lymphocyte distributions and in vitro lymphocyte proliferation following Concanavaline A stimulation) were found. The authors concluded that the housing conditions did not impact on the functioning of the immune system. These findings suggest that cortisol levels do not have major consequences for disease resistance.

4.3. Performance and carcass quality

4.3.1. Performance

In general, when performance data originating from straw-based systems is compared with data originating from slatted systems, there is a higher level of daily weight-gain and feed intake in straw systems. Sometimes a more efficient (lower) FCR is also found, although this effect is not always significant (Ruijterkamp, 1987; Schouten, 1991; Lyons et al., 1995; Morgan et al., 1998; Guy et al., 2002b; Van de Weerd et al., 2005). A more efficient FCR, which is associated with a significantly shorter finishing period, has economic implications (Gentry et al., 2002a; Guy et al., 2002b). Such findings are explained through greater general levels of activity and exploratory behaviour in straw-bedded systems leading to a higher feed intake (McKinnon et al., 1989; Lyons et al., 1995; Morgan et al., 1998). Other factors thought to influence performance are increased gut capacity in pigs housed in straw-based systems in conjunction with the extra energy extracted from consuming straw. In addition, straw provides pigs with an opportunity to keep warm and thus save energy (Morgan et al., 1998) reflecting an increased ability to control their micro-environment (Fraser, 1985; Fraser et al., 1991). However, the effects on performance cannot always be solely attributed to the effect of straw. This is because in ‘systems-studies’ many factors will be confounded. For example, the effects of straw can be confounded with the effects of different types of ventilation or different types of flooring. The available space per pig is sometimes mentioned as being confounded with the effects of straw (e.g. Fraser et al., 1991) and that increasing exercise may explain increases in feed intake. However, a study investigating the effect of space (related to exercise) does not support this, as exercise does not affect pig performance (Gentry et al., 2002b). The type and amount of enrichment provided can have a greater influence on performance and behaviour than floor space per se (Beattie et al., 1996; Kelly et al., 2000). However, if space becomes too restricted (overcrowding), enrichment objects cannot alleviate the negative effects of crowding on performance (Pearce and Paterson, 1993).

4.3.2. Carcass quality

The effects of straw-based systems on carcass quality are not consistent. No differences in back-fat thickness were found when comparing pigs housed in straw-based systems with pigs housed in slatted systems (Lyons et al., 1995; Klont et al., 2001; Guy et al., 2002b; Van de Weerd...
et al., 2005). However, in other studies, significantly higher levels of back-fat have been found in pigs from straw-based systems (Ruitterkamp, 1987; Gentry et al., 2002a). Carcass weights have been found not to differ (Klont et al., 2001; Van de Weerdt et al., 2005), to be higher for pigs from straw-based systems (Lyons et al., 1995; Gentry et al., 2002a) or to be lower in pigs from straw-based systems (Guy et al., 2002b). As mentioned above, these contrasting results may reflect differences between the systems studied. The straw-based systems studied vary from a thin layer of straw in the straw-flow systems to a deep bed of straw. The slatted systems used as controls include both fully and partly slatted systems. It is also known that hot and cold carcass weights are influenced by gut-fill and it not always stated which measure has been used for calculations. Furthermore, some studies compared pigs at a defined target age (Lyons et al., 1995; Gentry et al., 2002a) while, in other studies, pigs were sent to slaughter when they reached a defined slaughter-weight which may have influenced carcass quality (Guy et al., 2002b).

4.4. Meat quality

Post-mortem muscle pH (Guy et al., 2002b) and meat quality variables (MLC, 2004) appear to be unaffected by whether pigs are housed in fully slatted or straw-based housing-systems. Similarly, meat quality is unaffected by whether pigs are housed in partly slatted pens or larger straw-bedded pens (Geverink et al., 1999). However, in a study with a similar design, effects of straw enrichment were found (Klont et al., 2001). Lactate formation in Longissimus Lumborum muscles post-mortem and the percentage drip loss at day two and five after storage were found to be lower in pigs housed in strawed pens, indicating an improved water-binding capacity of the meat. Other variables such as meat colour, pH and temperature were not found to differ between groups.

Loins from 1500 pigs which had previously been housed in a system with deep straw bedding (Gentry et al., 2002a) were firmer than from pigs housed on concrete slats, which may be due to higher levels of intramuscular fat or increased back-fat. The loins also had lower initial pH measurements indicating a possible advantage in water-holding capacity; however the 24 h measurement did not differ. There were no other differences in meat quality or taste panel scores. Maw et al. (2001) reported that straw influences eating quality because pigs reared in big straw yards produced bacon with a stronger fried-meat flavour than pigs reared on flooring without bedding. However, it is also possible that group size (>50 pigs/group) might have played a role in producing these results.

5. Housing systems with point-source enrichment-objects

5.1. Behaviour

5.1.1. Exploration

Pigs are motivated to explore novel stimuli of little biological value (see Day et al., 1998). Exploration directed towards novel objects is much more persistent than activity directed towards familiar objects, and interest in novel objects declines rapidly (Wood-Gush and Vestergaard, 1991). It is known that this type of exploration is influenced by the type of rearing system in which the pigs are housed. Pigs housed in enriched pens (branches, logs, stones, chain, hanging branch) were found to spend less time examining a novel area adjacent to their home pen and performed less frequent ‘scampering’ and ‘sparring’ behaviour compared with pigs housed in barren pens (Wood-Gush et al., 1990). The enriched pigs also spent less time examining a novel object (a football, bucket or tyre) presented in their home pen. Hemsworth et al. (1996) found that pigs reared in a relatively barren-environment were highly and consistently motivated to physically interact with novel stimuli (either a human or an object). These results support the hypothesis that pigs reared in barren environments have elevated levels of exploratory motivation in comparison to pigs reared in enriched environments (Stolba and Wood-Gush, 1980) (see Section 3.1.6).

5.1.2. Home pen behaviour

Enrichment objects can influence the behaviour of pigs in their home pen. The provision of a ‘pig mobile’ (an iron cylinder fixed to the floor with a horizontal, rotating cross and four rubber dog toys suspended on chains) and plastic balls made pigs in slatted pens less ‘inactive’ (lying). These animals also exhibited more positive social interactions and play (Guy et al., 2002d). Male pigs housed in crowded pens, but enriched with a set of objects (either chains, lifter bars and a rubber tyre or cloth strips, swivel wheel and dustbin lid), showed less ‘sitting inactive’ and less ‘feeding’ behaviour compared with pigs housed in barren control-pens (Pearce and Paterson, 1993). However, in contrast to these results, Hill et al. (1998) found that enrichment objects (spring loaded chains and rubber hoses on chains) did not affect the overall duration of basic ‘lying’, ‘feeding’ and ‘drinking’ behaviours. Similarly, Day et al. (2002b) found that different enrichment objects (either a loop of metal chain, a small amount of chopped straw or a destructible, nutritious toy) did not affect behaviour in the home pen, although there was a trend that there was more pen-directed behaviour in the barren and chain treatment. The diversity of enrichment objects used, and the amount of enrichment provided (either a single object or a set of objects), may well explain these different results.

5.1.3. Characteristics of effective enrichment

The type of behaviour that a pig directs towards enrichment objects can reveal whether these objects are effective as enrichment because the intensity of the interaction reflects its salience to key motivational systems such as exploration, play and feeding. Van de Weerdt et al. (2003) developed a systematic methodology to identify the characteristics of objects which capture and sustain interest of pigs. In a high throughput screening exercise, the behavioural responses of pigs to a broad range of objects was measured. The range of objects was chosen on the basis of the different characteristics they offered pigs. It was found that the main characteristics of the objects used most intensively by weaner and grower pigs were...
‘ingestible’, ‘odorous’, ‘chewable’, ‘deformable’ and ‘destructible’. These characteristics are often associated with rootable substrates and linked to motivations such as exploration and foraging, which are important behavioural systems of pigs (Fraser, 1983/1984; Wood-Gush and Vestergaard, 1991). Our findings (Van de Weerd et al., 2003) are in accordance with other literature sources, and begin to explain why pigs have a stronger preference for some forms of enrichment objects than for others.

A number of studies confirm that ‘chewable’, ‘deformable’ and ‘destructible’ point-source enrichment-objects are the most valued by pigs. Feddies and Fraser (1994) studied the features of non-nutritive chewing and found that pigs used objects (cotton cords or rubber strips) more if they could perform destructive chewing in which they altered, unravelled, or removed pieces of the object. Straight chewing targets were preferred over looped targets. Apple and Craig (1992) exposed female piglets, housed within two pen-size treatments, to four different objects (knotted nylon rope, rubber hose, metal chain, and hourglass shaped rubber dog toy) in succession. They found that the pigs preferred the rubber dog-toy to the other objects. Pen size was not found to influence toy use. Horrell and Ness (1995) offered pigs a choice between a number of objects. They found that a rope was more popular than dog bones or chains. Grandin (1989) showed that soft, pliable, objects (e.g. a suspended cloth strip or hose) are preferred over hard chains and that pigs change their preferences for hanging cloth-strips to hanging rubber-hoses after seven days. Hill et al. (1998) found that finisher pigs interacted more with a hose than with chains, although the same pigs, when they were younger (weaning phase), did not show a preference. Scott et al. (2006b) found that pigs interacted more with a hopper filled with shreds of unmolassed sugar-beet-pulp than a commercially available hanging plastic-object with chewable protuberances (Bite-Rite, Ikadan System, Denmark).

Bracke et al. (2006) evaluated the welfare benefits of enrichment materials for weaner and grower pigs. This formalised review covered several papers that are included in the current review. Their tentative conclusions were that metal objects, such as chains, are not suitable enrichment materials for pigs; rubber, rope, roughage and substrates may be sufficient; and straw and compound materials (combinations of objects and/or substrates) are best. Experimental support for the conclusion that chains are not suitable enrichment has been published by a number of authors (Grandin, 1989; Horrell and Ness, 1995; Hill et al., 1998; Stubbe et al., 1999; Day et al., 2002b).

Synergistic interactions between characteristics may make an object even more interesting for a pig (Van de Weerd et al., 2003), similar to compound enrichment (Bracke et al., 2006). Zonderland et al. (2001) tested the properties of four different materials (rope, wood, chain and metal pipe) and found that a combination of ‘flexibility’ and ‘destructibility’ proved to be most interesting for the pigs tested.

5.1.4. Habituation to less effective enrichment

One of the main consequences of providing partially effective (or ineffective) enrichment is that the pigs lose interest in it quickly over time (e.g. Grandin, 1989; Blackshaw et al., 1997). Therefore, the rate of habituation should be measured in addition to the level of initial object use. Habituation to certain objects can occur after just a few days (Van de Weerd et al., 2003). Heizmann et al. (1988) offered four different objects in succession (a metal chain, a dried cow's tendon, a car tyre or a sterilised cow bone) to finisher pigs in straw pens. The chain, tendon and car tyre were all used on the first day of exposure, but on the second day their use had already decreased by more than half, and this decreased even further on the following days to less than 2% of the observation time. The cow bone produced higher levels of interactions on the first day comparison with the other objects; however, interest also decreased by more than half on the second day, but then remained approximately at that level. These findings demonstrate the level of exploratory motivation decreases as a pig become progressively familiar with a novel enrichment object. If an object is unable to sustain interest for a protracted period of time, pigs are effectively exposed to barren environments with the associated risks of harmful social behaviour developing as motivated behaviours become redirected towards inappropriate stimuli such as pen-mates.

One of the goals in designing any new enrichment strategy is to strive for continuous use of the objects or substrates provided. While this goal in itself is challenging enough, it should be remembered that the type of point-source enrichment-object has to be selected in accordance with the pigs' requirements, for example, with increasing age. Krötzl et al. (1994) found that pigs interacted with a metal cylinder, holding a bar of chopped straw compressed with molasses, more than a container holding chopped straw or a wooden log suspended on chains. Furthermore, as the age of the pigs increased, the interest in the container holding chopped straw increased while it decreased for the other objects. Such changes in object use may reflect motivational changes occurring during behavioural development. However, the authors also conceded that the preferences may have been influenced by the physical size of the pigs because, as they grew, they could reach the straw container more easily.

5.1.5. Motivation and frustration

If an enrichment strategy is poorly designed, it is possible that ineffective enrichment may increase the motivation of animals to perform a specific behaviour such as chewing. If they are not able to express the resulting behaviour adequately, this can lead to a conflict situation causing frustration (Mench, 1998; Van de Weerd et al., 2006). For example, a point-source enrichment-object that increases the level of feeding motivation, but is not able to accommodate foraging behaviour may lead to the redirection of rooting and chewing behaviour towards inappropriate stimuli such as pen-mates. Young (2003) commented that a failure to provide an appropriate outlet for species-specific behaviour can mean that the animal is unable to obtain the reinforcement due to the incompatibility between the reward and the behaviour required to obtain the reward. Lewis (2000) studied frustration in grower pigs by providing non-functional feeders after a
period of fasting. They found that simple enrichment objects, such as a chain or a ball, provided an outlet for frustration as they attracted object-directed behaviour instead of this activity being expressed as ‘sitting’ or ‘manipulation’ directed at the pen, feeder or a pen-mate. However, these effects were only observed in the short-term (2 h), and long-term effects were not studied. In other studies, the long-term provision of chains (considered to be less effective enrichment) did not prevent severe levels of tail-biting (Stubbe et al., 1999; Zonderland et al., 2003). These results suggest that frustration might be another factor that contributes to the expression of harmful social behaviours such as tail-biting.

5.1.6. Pig specific enrichment

Some point-source enrichment-objects have been found to have positive effects on harmful social behaviour by reducing ‘belly nosing’ and ‘tail-biting’ (Kröttl et al., 1994; Guy et al., 2002d; Rodarte et al., 2004). However, as outlined above, it is very important to design enrichment according to pig-specific requirements for it to be most effective. This approach was taken in a study in which four enrichment objects were designed to incorporate a combination of the main characteristics identified in previous work (Van de Weerd et al., 2003) and were provided to groups of growing pigs with undocked tails (Van de Weerd et al., 2006). The four different enrichment objects were a substrate dispenser providing straw, a rootable feed-dispenser providing flavoured feed, a liquid-flavour dispenser providing flavoured water following manipulation of chewable rods, and a commercial object with chewable protruberances (Bite-Rite, Ikadan System, Denmark). The pigs’ use of these objects was compared with the use of a full bed of straw. The use of the full bed of straw and of the straw rack was highest compared to the other treatments (11.5% and 3.6% of observations). Groups of pigs provided with the liquid dispenser (which experienced technical problems) and the Bite-Rite had the highest levels of tail-biting incidents (100% and 83% of pens respectively). This shows that objects such as substrate dispensers providing a limited amount of a substrate can be offered as good alternatives to straw.

Other studies have reported positive effects of offering limited amounts of substrate. It is possible to offer limited amounts of straw to groups of pigs using a rack or dispenser. Zonderland et al. (2003) found that severe tail-biting was prevented by placing a straw dispenser in a partly slatted pen; however, this form of enrichment was unable to stop mild levels of tail-biting. Buré et al. (1983) found that straw provided in hanging metal baskets reduced the number of tail-bitten pigs, and when straw was offered in a rack, the ‘rooting of pen-mates’ and ‘chewing of pen walls’ was reduced. Fraser et al. (1991) found that the use of a straw rack also influenced diurnal patterns of activity. Pigs with the straw rack were more active when fresh straw was provided, but they were less active than pigs housed in barren conditions at other times.

The simplest way of providing a limited amount of straw is to throw it directly into the pen (Van Putten, 1980; Day et al., 2002b). A handful of straw per pig per day occupies attention for up to 1.5 h per pig a day in partly slatted pens (Van Putten, 1980). Zonderland et al. (2003) investigated whether a handful of straw daily could be used as a curative measure when tail-biting had started. However, this intervention only had a short-term effect on reducing tail damage, and was not able to eliminate tail-biting completely in the longer-term. Therefore, a well designed substrate dispenser might be more effective than a handful of straw. Stubbe et al. (1999) offered a straw container (incorporating a piece of wood attached to chains that the pigs could manipulate to release straw into a rooting dish) to grower pigs housed in partly or fully slatted systems and compared their behaviour with groups housed in either a barren pen, or a pen with a metal chain. The pigs used the substrate dispenser well throughout the finishing period and no tail-biting was observed (as opposed to the barren and chain treatments) despite the fact that some groups of pigs used had undocked tails.

Other types of substrates provided in hanging racks or on trays are also able to reduce levels of harmful social behaviour. Beattie et al. (2001) found that spent mushroom-compost offered on a suspended overhead-rack reduced the number of pigs engaging in pen-mate-directed behaviour. The percentage of animals with bitten tails that had to be removed from the study was also significantly lower in the enrichment treatment compared with the fully slatted control-treatment. A trough containing sterilised earth increased ‘rooting’ behaviour, decreased ‘sitting/lying inactive’ and reduced ‘chewing of pen mates’ (Wood-Gush and Beilharz, 1983; Appleby and Wood-Gush, 1988). A rooting tray with peat or compost reduced ‘belly nosing’ and ‘tail- and ear-chewing’ (Buré et al., 1983; Horrell and Ness, 1995). A rooting tray filled with potting soil and mushroom compost (‘rooting enrichment’) was used most by weaner pigs in comparison with other types of enrichment, although only the ‘nosing enrichment’ (a foam rubber mat attached to the wall) managed to reduce ‘belly nosing’ behaviour (Bench and Gonyou, 2006).

The above listed studies show that when straw cannot be used as enrichment (e.g. in slatted systems), objects such as substrate dispensers can be offered as good alternatives. These types of objects provide a limited amount of a substrate, but still allow pigs to direct nosing, rooting and chewing activity towards an ‘appropriate’ stimulus so as to not encourage the development of undesirable harmful social behaviour such as tail-biting.

5.1.7. Handling and contact with humans

Point-source enrichment-objects do not seem to affect the ease of handling of pigs. For example, a novel, nutritious, destructible point-source enrichment-object did not affect the handling of pigs when moving them to and from the home pen to a holding area, or when moving pigs from the home pen, past a novel object (either a yellow bucket or a white plastic bag) and into a raceway (Day et al., 2002b). Hill et al. (1998) found that the time required to weigh a pen of pigs was also not influenced by offering point-source enrichment-objects in the home pen. However, Grandin (1989) reports that the effects on handling are unclear. In some trials, increased contact with humans and object exposure made pigs easier to move.
(less excitable), whereas other trials showed the opposite. These results suggest that there might be an interaction between the type of enrichment and the type of handling, which may explain some of the ambiguity in the literature. In addition, the conclusions drawn may also depend on what aspect of the environment is being enriched (e.g. enrichment of the social environment or the physical environment, Van de Weerd and Baumanns, 1995).

In human contact tests, the fear of humans can be reduced by exposure to enrichment objects. The latency to approach a person in a home pen was found to be significantly reduced in piglets housed in pens enriched with hanging ropes and rubber tyre tubes (Rodarte et al., 2004). Pearce et al. (1989) found that male pigs, housed in pens enriched with objects (chains, bar, rubber tyres), had a reduced fear of humans regardless of whether they were being handled pleasantly or unpleasantly (use of a shock prod). They also found that during weekly handling sessions in the home pen, pigs from the barren control-pens interacted more with the handler. It was concluded that these increased social interactions could be a substitution for the lack of stimulation in the environment. Pearce and Paterson (1993) found that male pigs housed in crowded pens that were enriched with a set of enrichment objects (either chains, lifter bars and a rubber tyre or cloth strips, swivel wheel and a dustbin lid) showed reduced reactivity to both a novel object (bucket) lowered in an open field, and a human being entering the arena. Pigs from the crowded, barren pens (controls) were quicker to approach and interact with the object and the human. These results add further support to the hypothesis that pigs housed in barren environments posses higher levels of exploratory motivation than pigs housed in enriched environments. In the study of Pearce and Paterson (1993), activity in the open field did not differ between the pigs from the two treatments. Other studies have found that the contact time with an experimenter was not affected by exposure to certain enrichment objects such as spring-loaded chains and rubber hoses on chains (Hill et al., 1998), a loop of metal chain, a small amount of chopped straw or a novel, destructible, nutritious toy (Day et al., 2002b). This suggests that the type of enrichment and the quantity of stimuli provided influences the extent of the effect on (fear) behaviour.

5.1.8. Aggression
A number of studies have investigated the effect of enrichment on the aggression that typically occurs during the post-weaning mixing of young pigs. Barriers or opportunities to hide appear to have a positive effect on the levels of aggression. Waran and Broom (1993) found that when piglets were provided with a metal barrier behind which they could hide, the frequency of aggressive interactions was significantly lower. Piglets that were the recipients of most aggressive behaviour used the barrier more frequently, showing it offered an escape/defuge during aggressive encounters. McGlone and Curtis (1985) reported that piglets provided with hide areas in the wall, to stick their heads and shoulders in, had significantly shorter attack durations during the initial 30 min after regrouping. Ishiwata et al. (2002) also found that a hiding box reduced the agonistic behaviour of weaner pigs on the first day after mixing.

The provision of point-source enrichment-objects can also reduce aggression. Schaefer et al. (1990) found that newly weaned pigs showed less aggression during the first week of exposure when they were offered either a suspended sugar-mineral block, or rubber belts hanging on metal bars (less head-to-head aggression) than pigs housed in pens without objects. The lowest level of aggression was seen in the pens with the rubber belts. In the same study, young female pigs housed in pens containing car tyres on horizontal chains showed a lower frequency of aggressive acts than pigs housed in similar pens without enrichment. The pigs used the tyre mainly for ’chewing’ and ’pushing’ (Schaefer et al., 1990). However, in a separate study, when tyres were provided at the time of mixing (Ishiwata et al., 2004), they did not reduce aggressive interactions. When pigs were already familiar with a car tyre, the number and duration of attacks received by the pigs after mixing was greater than when there was no tyre present. The authors explained this by pigs seeking ownership of the tyre (Ishiwata et al., 2004).

In addition to the findings of Schaefer et al. (1990) and Ishiwata et al. (2004), other studies have found that levels of aggression are reduced when point-source enrichment-objects are added to barren pens. For example, lower levels of aggression were observed in weaner piglets provided with an old metal and plastic sow neck-tether (Blackshaw et al., 1997), with a trough containing sterilised earth (Wood-Gush and Beilharz, 1983; Appleby and Wood-Gush, 1988) or with objects such as a rubber ball, small rubber tyre, PVC pipe, plastic drink bottle or an ice cream container (Jolly et al., 2002). Less pig-to-pig interaction was seen in groups of weaner pigs provided with commercially available objects (Wood et al., 2003), but in another trial the same authors reported that while the piglets with the objects expressed fewer vices, they fought more often. The authors did not specify the types of objects provided. The provision of point-source enrichment-objects (suspended bicycle tyre tubes and baseball balls on the floor) to grower pigs of different ages reduced the levels of aggression after mixing as compared to controls (Kamada et al., 1993). Cloth strips were found to reduce fighting in newly mixed pigs (Grandin, 1989) and a suspended rack with mushroom compost presented to dry sows reduced the levels of aggression on the first day of mixing (Durrell et al., 1997). General home pen aggression in groups of grower pigs was reduced by the provision of a ‘pig mobile’ (an iron cylinder fixed to the floor with a horizontal, rotating cross and four rubber dog toys suspended on chains) and plastic balls (Guy et al., 2002d), but was not affected by sets of either chains, lifter bars and a rubber tyre or cloth strips, swivel wheel and a dustbin lid (Pearce and Paterson, 1993). In summary, the majority of these studies show that point-source enrichment-objects have the potential to reduce aggression among pigs.

5.2. Health and physiology

Only a limited number of studies have evaluated the effects of enrichment objects on aspects of health and physiology.
5.2.1. Respiratory system

Beattie et al. (2001) found no negative effects on lung-damage scores when pigs were offered a rack containing spent mushroom-compost.

5.2.2. Stomach lesions

Day et al. (2002a) found that the level of stomach lesions in finisher pigs was unaffected by offering pigs four different forms of enrichment (barren pen, a loop of metal chain, a limited amount of chopped straw or a destructible, nutritious toy).

5.2.3. Wounds

As outlined earlier, the hiding box that was provided to weaner pigs by Ishiwata et al. (2002) reduced aggressive interactions. However, despite this positive effect, the level of injuries on the back of the piglets’ ears was unaffected by treatment (see also Section 5.1.8). In subsequent experiments by Ishiwata et al. (2004), pigs were provided with a car tyre. This form of point-source enrichment-object, did not reduce agonistic interactions, however, they found a reduction in injury scores in pigs (but only in those pigs which had no previous experience with the tyre). McGlone and Curtis (1985) found a good agreement between interactions. However, despite this positive effect, the level of injuries on the back of the piglets’ ears was unaffected by offering pigs four different forms of enrichment (barren pen, a loop of metal chain, a limited amount of chopped straw or a destructible, nutritious toy).

5.2.4. Adrenal glands

Pearce et al. (1989) examined the ratio of a cross-sectional area of adrenal cortex to medulla area to evaluate adrenal hypertrophy as an index of stress, and found no differences between male pigs housed in pens enriched with objects (chains, bar, rubber tyres) and controls within two handling-treatments.

5.2.5. Plasma cortisol

Pearce and Paterson (1993) found that the provision of a set of objects (chains, lifter bars and a rubber tyre or cloth strips, a swivel wheel and a dustbin lid) to male pigs housed in crowded pens did not influence the plasma-cortisol concentrations (after an ACTH challenge). Cortisol concentrations were elevated in pigs housed in crowded pens, indicating that these pigs experienced chronic stress compared with pigs housed in uncrowded pens. The mean basal-concentration of cortisol did not differ between the enrichment treatments and also did not differ from pigs housed in uncrowded pens. Similar findings are reported by Rodarte et al. (2004) for basal salivary cortisol concentrations in early-weaned piglets housed in pens enriched with a hanging rope and rubber tyre tube, where cortisol concentrations did not differ from pigs housed in barren pens.

5.2.6. Neurobiological studies

There is a vast body of literature describing the effects of enrichment on brain plasticity in mice and rats (for a good overview, see Renner and Rosenzweig, 1987; Young, 2003). However, it appears that only two studies investigating the effects of environmental enrichment on the brains of pigs have been published (Grandin, 1989; Jarvinen et al., 1998). These studies show that the brains of pigs housed in complex environments (straw and enrichment-objects and outdoor runs in Grandin, 1989 and outdoor environments in Jarvinen et al., 1998) differ from those of pigs from barren environments (indoor barren pens in both studies). The effects were evident in the somatosensory (Grandin, 1989) and auditory cortex (stellate cell dendritic morphology) and different rates of cell maturation in the primary, auditory, somatosensory and visual cortex (Jarvinen et al., 1998). The effects found in both studies were modest, but this might be explained by the relative similarity of the housing systems studied. This contrasts with much of the rodent literature, where animals housed in isolation (impoverished conditions) have been compared with animals from socially enriched conditions, including cage-mates and objects (see Renner and Rosenzweig, 1987 for discussion of the effects of these different aspects). The pig studies show that different environments can alter the organisation of the brain when pigs are exposed to them during early life, but it remains unknown whether exposure to different environments can also influence adult brain-morphology as is often the case in rats and mice. According to Jarvinen et al. (1998), the enrichment effects can be used to assess different farm production-environments and might indicate whether standard husbandry practices influence neural organisation. Sensory input affects the development of the brain, so brain parameters could be useful tools to evaluate the effects of environments differing in enrichment levels. However, more work should be done to interpret the meaning of these effects.

5.3. Performance and carcass quality

5.3.1. Single objects

The effects of point-source enrichment-objects on performance are not consistent. Objects such as chains, tyres, balls, metal bars, nutritious objects, chewable rubber objects or cloth strips do not influence performance parameters in grower or finisher pigs (Kamada et al., 1993; Pearce and Paterson, 1993; Day et al., 2002a; Zonderland et al., 2003). No differences in feed efficiency and carcass quality parameters (back-fat at last rib, or eye muscle area) were found between pigs from pens enriched with objects (chains, lifter bar, rubber tyres) and controls (Pearce et al., 1989). Hill et al. (1998) found an effect on performance in one of two genetic lines of pigs provided with objects (spring loaded chains and rubber hoses on chains). The effect was an increased daily weight-gain and lower food-conversion ratio. No differences in back-fat thickness and carcass weight were reported. Krötzl et al. (1994) reported that pigs from different enrichment treatments (pens with either a cylinder holding a bar of chopped straw compressed with molasses or a container holding chopped straw or a wooden log suspended on chains) had higher daily weight-gain and lower FCRs than pigs housed in barren pens. However, it was not reported whether these differences were statistically significant. A higher daily weight-gain in comparison with pigs from barren pens was also reported by Rodarte et al. (2004) for
early-weaned piglets exposed to a hanging rope and rubber tyre tube, and by Schaefer et al. (1990) for young pigs provided with either hanging car tyres, suspended sugar-mineral blocks or hanging rubber belts.

In a study by Van de Weerd et al. (2006) several enrichment objects designed according to pig requirements were compared with a straw treatment as control. Feed efficiency related parameters did not differ between pigs provided with a rootable feed dispenser and pigs housed with a straw bed. However, pigs provided with a commercially available chewable object consisting of a plastic cone with four protruding plastic sticks (Bite-Rite, Ikadan System, Denmark) had a significantly lower feed intake and weight gain than the pigs housed with a straw bed, although the FCR did not differ significantly. In another study, similar effects on production parameters were found between pigs housed in partly slatted pens with a Bite-Rite and pigs housed in straw-bedded pens (Van de Weerd et al., 2005). No differences in carcass-quality (cold carcass weight or back-fat thickness at the P2 position) were found between pigs housed in strawed pens or object-enriched partly slatted pens (Van de Weerd et al., 2006) or strawed pens versus partly slatted pens with Bite-Rite objects (Van de Weerd et al., 2005).

5.3.2. Substrate dispensers

Rootable substrates presented in different ways do not appear to influence feed efficiency parameters when compared with barren control pens, straw-bedded pens or pens with other enrichment objects. Examples in the literature include straw dispensers (Buré et al., 1983; Zonderland et al., 2003; Van de Weerd et al., 2006), a compost tray (Buré et al., 1983) and a mushroom compost rack (Beattie et al., 2001). The mushroom compost rack was also found not to influence carcass quality (back-fat thickness at the P2 position). Small amounts of straw provided daily also do not appear to affect performance (Day et al., 2002a; Zonderland et al., 2003).

The studies in the previous two sections show that pig-specific enrichment objects do not influence performance parameters negatively and that negative effects are mainly found when the enrichment provided does not fulfil all the pigs’ requirements.

5.3.3. Weaner pigs

A number of studies have investigated the effect of enrichment on the growth of pigs after weaning by trying to reduce the levels of aggression that typically occur after mixing. Weight gain appears to be improved when piglets are provided with refuges in which to hide (McGlone and Curtis, 1985; Waran and Broom, 1993), but the hiding box studied by Ishiwata et al. (2002) appears not to have had any change in the growth rates of weaner pigs when they were offered a metal and plastic object (old sow neck tether) when it was presented fixed or free on the floor (Blackshaw et al., 1997).

5.4. Meat quality

Hill et al. (1998) compared the meat quality of pigs housed in groups that were either enriched with pointsource enrichment-objects (spring-loaded chains and rubber hoses on chains) or were housed in barren conditions. Measurements of pork quality (flavour, tenderness, juiciness and mouth-feel) did not differ between the treatments.

6. Discussion

The aim of this paper is to critically review the existing literature concerning enrichment for pigs housed in intensive (indoor) production systems. Our objective is to provide clarity as to what constitutes successful enrichment. In this section we move towards a synthesis by discussing the merits of the different types of environmental enrichment against our four criteria of success. Environmental enrichment: (1) should increase species-specific behaviour, (2) should maintain or improve levels of health, (3) should improve the economics of the production system, and (4) should be practical to employ

6.1. Alternative enriched systems

Alternative enriched systems offer environmental diversity to pigs and, if designed correctly, allow the expression of species-specific behaviour and control over the environment. It is generally assumed that the expression of such behaviours is highly motivated, and is rewarding for the animal to perform. The organisation of their behaviour changes as a higher relative diversity of species-specific behaviour is displayed. It is also known that an individual’s learning, adaptability, handling and social behaviour are all positively influenced by environmental enrichment. Despite the existence of such strong behavioural indicators of improved welfare, the limited number of studies of pig health and physiology in alternative enriched systems has failed to show positive effects.

The performance of pigs in alternative enriched-housing-systems is similar (or in some cases, slightly better) when compared with barren systems. However, alternative enriched-housing-systems may not always be very practical to manage in commercial practice due to complicating factors such as cleanliness and ease of animal handling. Such higher-welfare livestock-systems have a high set-up and labour cost and, therefore, inevitably are associated with a higher cost of production. It seems that most improvements in farm animal welfare have little noticeable effect on final food prices (McInerney, 2004), and there is debate about whether such costs should be absorbed by the consumer, retailer, processor or producer. To tackle this type of debate, alternative enrichment systems should be studied in an integrated way by modelling the technical, management, animal welfare
and the environmental impacts (e.g. emissions) of novel systems.

6.2. Straw-based systems

Straw has been shown on many occasions to increase the expression of species-specific behaviour in the pig as it acts as an exogenous cue and outlet for motivated behaviours such as exploration, foraging, and play. The expression of such behaviours is thwarted in barren environments. The provision of straw to pigs often results in a significantly lower incidence of undesirable, harmful, social behaviour, including tail-biting.

Almost all of the welfare enhancing effects of straw can be fulfilled by alternatives, but the advantage of straw is that it serves all of these functions simultaneously (Tuyttens, 2005). Bedding material can be accessed from a lying position which undoubtedly increases the proportion of time that pigs spend manipulating straw. Despite this knowledge, it is still not known how straw functions to modify behaviour and what properties pigs find so rewarding. If more research were to be conducted in this area, the resulting knowledge could then be applied to design suitable enrichment objects as alternatives to straw.

The relation between straw and health and physiology appears to be dependent on the disease or health variable studied (Tuyttens, 2005). Certain diseases/injuries are more prevalent in strawed housing systems, whereas other diseases/injuries are less prevalent. This lack of clarity is typified when the effects of straw on the respiratory are studied. The results may depend both on the types of lesions investigated, and the type of housing system studied. Foot lesions appear to be more common in straw-based systems, but are not necessarily more severe than those observed in barren slatted-systems. It also appears that each type of flooring is associated with different types of lesions. More seriously, pigs housed in barren systems appear to have elevated levels of salivary cortisol compared with pigs housed in straw-based systems. This may indicate that pigs housed in barren systems could be in a state of chronic stress, which might be linked to a psychological state of depression. This needs further research.

Using straw can bring economic benefits, as a lot of studies report that the performance of pigs is better in straw-based systems than in slatted systems. However, ‘system-studies’ usually vary in many aspects in addition to the type of flooring. Such variations can potentially confound results and make direct conclusions difficult. Results from a more controlled study comparing fully slatted and straw-based finishing-systems showed no consistent effects of housing on growth performance and carcass quality (MLC, 2004). The effects of straw on carcass quality reported in other studies are not consistent, but generally no large differences have been found (although some factors may have been confounded in these studies as well). Therefore, results have to be interpreted with care. If there are no economic or health constraints, then straw is very practical to use and associated with many welfare benefits.

6.3. Point-source enrichment-objects

We have previously studied the characteristics of enrichment objects that capture and sustain the attention of pigs. These were identified as being objects or substrates that are ‘ingestible’, ‘odoriferous’, ‘chewable’, ‘deformable’ and ‘destructible’; characteristics that are often associated with rootable substrates (Van de Weerd et al., 2003). It is known that objects such as dispensers can be used to offer a limited amount of a substrate as an alternative to a straw bed. Such dispensers allow pigs to root and forage and have been demonstrated to prevent the development of high levels of tail-biting. Compound enrichment or combinations of enrichment (such as a straw and peat or a combination of ropes and rubber hoses) are also effective forms of enrichment (Bracke et al., 2006).

When pigs are offered several different substrates in preference tests or behavioural demand studies, straw is not always the preferred choice (Beattie et al., 1998; Van de Weerd et al., 2003; Jensen et al., 2004). This means that when substrate dispensers are used as enrichment alternatives to a straw bed, substrates other than straw might be equally suitable or even more attractive to pigs. Beattie et al. (1998) suggest that particle size and texture, but not so much moisture content, play a role in these preferences as these might be associated with releasing rooting behaviour.

At present, the use of chains and car tyres is still fairly widespread on farms. The findings of studies covered in this literature review and the review by Bracke et al. (2006) confirm that these objects should not be recommended for long-term use, as they can quickly lose their novelty factor.

Due to a limited number of studies, it still remains unclear whether the ease of handling pigs is affected by exposure to object enrichment. In human contact tests, the fear of humans can be reduced by exposure to enrichment objects. If through exposure to enrichment, the handling of pigs improves, labour input could be reduced, bringing consequent improvements to both economics and animal welfare. More research is needed to clarify this.

Again, due to a limited number of studies, the effects of point-source enrichment-objects on health and physiology remain equivocal, although no negative effects have been reported. Cortisol concentrations appeared to be unaffected by enrichment objects. In general, the effect of enrichment objects on health parameters will be dependent both on whether suitable pig-specific enrichment is provided, and the level of underlying health challenge present on the experimental unit.

There is potential to reduce the level of skin lesions in newly mixed weaner-pigs by enriching pens with barriers or hiding areas. This is known to reduce the frequency and type of aggressive interactions. The effectiveness of these divisions depends on the type of refuge provided. Point-source enrichment-objects are also associated with reduced aggression in pigs of different ages, although not all objects are effective. Reducing aggression can have economic implications as it influences health and performance positively.

It is unknown whether the positive effects of enrichment on the welfare of pigs ultimately could improve their
resistance to disease. There is some support for this hypothesis in the veterinary literature, with papers suggesting that enrichment can reduce the possibility of pathogen transmission (Young, 2003), but this has not been systematically tested.

There is a potential bio-security risk if enrichment is moved between pens on a regular basis. High standards of bio-security should be maintained and enrichment should be regularly cleaned and disinfected (although this is not very different from current bio-security measures used on farms). In addition, before introducing novel objects on a large scale it should be assessed whether they can be chewed and ingested, potentially causing obstructions.

The economic implications of point source enrichment are not always clear as the majority of studies show no effects on performance and carcass quality. However, a wide range of different objects have been tested. Several studies showed improved performance in response to pig-specific enrichment. Several other studies show negative effects on performance, although it could be argued that the enrichment provided did not fulfil the pig’s species-specific requirements. The number of studies measuring meat quality is limited, and the effects described are small and seem to depend on the level of enrichment provided. The effects found suggest, however, that there is potential to improve the meat quality of pigs housed in sufficiently enriched environments and this has commercial implications. More research into the relation between housing conditions and meat quality is needed to elucidate this.

The biggest challenge for those designing point-source enrichment objects is to ensure that their enrichment is practical to use. Objects must be functional, easy to use and economic; otherwise their usage will remain low. If enrichment objects, such as straw racks, are not topped up regularly they will have a limited supply of substrate. This could potentially cause competition over access to fresh substrate such as straw (Fraser et al., 1991). However, such an increase in aggression has not been commonly observed in other studies where only a limited amount of straw was provided daily (Van Putten, 1980; Day et al., 2002a,b; Zonderland et al., 2003; Van de Weerd et al., 2006). Availability should also be monitored in relation to group size, to avoid competition over a valued resource and ensure the possibility of synchronised use by all animals in a group (see Docking et al., 2008). Another practical aspect to consider is that the limited size of point-source enrichment may restrict availability, which may be exacerbated by the location of the enrichment in the pen (Van de Weerd et al., 2006). For example, a pig using an enrichment object placed in the lying area may cause disruption of pigs that are resting. Access to an object that evoked low overall interaction was not restricted when either one or four objects were provided to pigs in groups of similar sizes (Scott et al., 2007). This may not be the case with objects that are more popular with pigs. Systematic research into the number and placement of point-source enrichment—objects in relation to group size has not yet been performed and would be valuable for making clear recommendations to the pig industry.

This literature review has shown that straw has the highest potential to meet the four criteria that defines enrichment as successful. However, it is possible to make successful point source enrichment if the wealth of knowledge available on enrichment for pigs is used. Despite this, there are knowledge gaps in our fundamental understanding of what substrates or objects enrich the lives of pigs. More research into the neurobiological effects of enrichment on pigs would assist in understanding why and how enrichment works. Brain parameters can then be used as tools to evaluate the effects of environments differing in enrichment levels.

Acknowledgements

This project was funded by Defra (project AW0137). Helpful comments on the manuscript were given by K. Breuer and S. Jewell.

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