Review

Why do pigs root and in what will they root?
A review on the exploratory behaviour of pigs in relation to environmental enrichment

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Abstract

The intention of the new European legislation on rooting materials for pigs is to improve the welfare of pigs. The question is: which materials are suitable rooting materials for pigs? To answer this question the motivation for exploration in pigs is elucidated and the needs of the pigs in this context are discussed. The effects of different materials on the behaviour of pigs are listed and the preferences of pigs for numerous different materials are compared. Based on the literature on the normal behaviour of pigs and studies on pigs’ use of and preferences for various materials, we conclude that in order to be a suitable rooting material the material must stimulate the exploratory behaviour of pigs for an extended length of time. Exploratory behaviour in pigs is best stimulated by materials that are complex, changeable, destructible, manipulable, and contain sparsely distributed edible parts.

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Keywords: Pig; Rooting; Motivation; Exploration; Environmental enrichment

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1. European legislation

According to a Commission Directive (2001/93/EC) “pigs must have permanent access to sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such, which does not compromise the health of the animals”. The intention of the directive is to improve the welfare of the pigs. By providing rooting materials the needs of the pigs for exploration will be met, and this, in turn, will reduce the risk of the pigs performing abnormal behavioural patterns that may be harmful to their penmates. However, the question is which characteristics such materials must have to remain attractive to the pigs for an extended length of time. In a recent review Bracke et al. (2006) ranked various rooting material categories according to a set of calculation rules based on positive points for expected welfare effects and negative points for unexpected welfare effects on a range of parameters. However, they did not offer any interpretation in relation to underlying motivation. In the following the effect of various rooting materials on the behaviour and welfare of growing and weaned pigs will be reviewed. The literature will be interpreted in relation to the natural behaviour of pigs and in relation to current motivational theory.

2. The exploratory behaviour of pigs

Pigs are omnivorous animals, their natural sources of food are found sporadically within a large home range area, and under natural conditions pigs spend a large part of their active time searching for food by exploring their surroundings. For instance, Stolba and Wood-Gush (1989) found that domestic pigs living in a semi-natural environment spent 52% of the daylight period foraging (rooting and grazing) and another 23% in locomotion and direct investigation of environmental features. The exploratory behaviour keeps the pigs abreast of the availability of resources, which is important for their survival when they are dependent on exhaustible and seasonal sources of food. Although the pig has been domesticated and fed by humans for several generations it posses the ability to adapt its foraging behaviour to the prevailing conditions. However, wild boar crosses used a more costly strategy than domestic pigs (Gustafsson et al., 1999), possibly because domestic pigs, which are selected for fast growth, are hungrier and therefore more efficient foragers.

Pigs explore their surroundings by rooting, sniffing, biting and chewing various food items as well as indigestible items. In this way they become familiar with their environment and the
various resources within it. The above-mentioned behavioural elements may also occur in other contexts than exploration, for instance chewing may also be viewed as consumatory behaviour.

2.1. Is rooting important?

Rooting behaviour appears to be a high priority behaviour in pigs. When pigs kept indoors were given access to earth (Day et al., 1995), and when the nose ring was taken off outdoor sows, they started to root immediately (Studnitz et al., 2003b). In addition, the longer gilts were kept without access to a rooting material, the more they rooted when given access to a pen with sphagnum (Studnitz and Jensen, 2002). The latter effect was, however, limited to the beginning of the experimental period where the rooting material was novel, suggesting that rooting is also stimulated by novelty. This is in accordance with Haskell et al. (1996a), who demonstrated that pigs rooted more when they knew they would find novelty.

When gilts were prevented from rooting through nose ringing they chewed, sniffed and manipulated the available rooting materials, while unringed gilts rooted in them. Thus, the total level of exploratory behaviour was not influenced by ringing the gilts (Studnitz et al., 2003a,b). In addition, there was no indication that the motivation to perform rooting behaviour increased over time in the ringed gilts since they showed the same level of rooting as the unringed gilts two days after removal of the nose ring (Studnitz et al., 2003b). Only if ringed gilts were prevented from performing other relevant exploratory activities, a higher level of abnormal behaviour was seen (Studnitz et al., 2003a), which indicates that pigs are able to substitute rooting with other relevant exploratory behaviours when rooting is prevented. This is supported by a study of Horrell et al. (1996), which showed that sows ringed in the upper rim of the snout explored the ground by means of their lower jaw instead of rooting. The studies suggest that rooting behaviour is an exploratory behaviour of high priority in pigs, but if pigs are prevented from rooting they will perform other exploratory behaviours more.

Jensen and Toates (1993) proposed that behavioural needs are a complex of performing the behaviour and obtaining the goal. Thus, exploratory behaviour, rather than a specific exploratory behavioural element, such as rooting, may represent a need in pigs. Jensen and Toates (1993) also emphasised abnormal behaviours as signs of suffering due to thwarting of a need. The housing in barren pens does result in a redirection of the exploratory behaviour towards penmates (e.g. Fraser et al., 1991), which supports the suggestion that exploratory behaviour represents a need in pigs.

2.2. The motivation for exploration

When pigs explore their surroundings, they may do so with a distinct purpose of for instance finding food or an attractive place to lie down (appetitive behaviour, also termed extrinsic exploration), or they may explore to gather general information on their surroundings (intrinsic exploration) (Berlyne, 1960; Wood-Gush and Vestergaard, 1989). Irrespective of the type of explorative behaviour performed, the pig will make use of the same behavioural elements, i.e. rooting, sniffing, and chewing. Exploratory behaviour may serve different purposes depending upon the type of motivation. Appetitive behaviour has an immediate goal (the consummatory behaviour) and is motivated by an acute need. For instance, the animal is hungry and it searches for food until it has found and consumed sufficient amounts. The food items found and consumed during appetitive foraging may have
feed-forward effects stimulating more appetitive foraging as suggested by Gardner and Gardner (1988). The part of the exploratory behaviour of pigs which is not controlled by an acute need is motivated by curiosity (intrinsic exploration). Curiosity may motivate the pig to search for novelty or a change of the environment, which is termed inquisitive exploration (Wood-Gush and Vestergaard, 1989; Day et al., 1995). Curiosity may also be stimulated by external stimuli, e.g. when pigs encounter and investigate something novel, which is termed inspective exploration (Wood-Gush and Vestergaard, 1989). Intrinsic exploratory behaviour serves to keep the pig informed about the environment and the resources available in it. Boredom has also been suggested to motivate intrinsic exploration. The concept of boredom assumes that animals explore to reduce boredom, while the concept of curiosity assumes that animals explore to reduce uncertainty. It may be argued that curiosity cannot motivate inquisitive exploration, because the stimuli are not impinging on the animal. However, as pointed out by Russell (1983), there is no problem if it is accepted that the animals can anticipate stimulus change. Further, Russell (1983) suggests that the two concepts should be viewed as having an inverse relationship; approaching and exploring new stimuli (curiosity) necessarily involves moving away from familiar stimuli (boredom). In the remaining of this review we will use the term curiosity.

3. Hunger and novelty in relation to exploratory behaviour

3.1. Hunger

Typically, growing pigs are fed ad libitum during the first half of the fattening period, whereas during the second half of the fattening period they are either fed ad libitum or restricted amounts of food. Restrictive feeding implies that the pigs are provided with the amount of food needed in order to obtain a profitable production of meat.

In pigs, several studies have demonstrated that restrictive feeding increases the occurrence of rooting behaviour, i.e. appetitive foraging (Stern and Andresen, 2003; Beattie and O’Connell, 2002; Day et al., 1995; Young et al., 1994; Wood-Gush et al., 1990), which implies that an increased motivation for exploratory behaviour is to be expected in growing pigs during the second half of the fattening period if they are fed restrictively. Correspondingly, one would expect pigs fed restrictively to perform more of other types of appetitive foraging, such as to chew straw more, compared with pigs fed ad libitum. However, this was not the case (Day et al., 1995) and even ad libitum fed pigs may have a motivation to chew (food preparation) that is not stimulated by the finely grounded food.

It has been demonstrated that although ad libitum feeding meets the pigs’ requirements for energy, the lack of essential nutrients, e.g. proteins, may increase the pigs’ motivation to perform appetitive foraging behaviour in the form of rooting (Jensen et al., 1993). Finally, although growing pigs are fed ad libitum some pigs in a group may still experience hunger. Pigs prefer to eat simultaneously (Nielsen et al., 1996), but this is not always possible due to the competition for access to food. Thus, subordinate pigs may not be able to maintain their ad libitum intake because they are reluctant to feed outside the normal feeding times, although food is always available.

Hunger increases the level of exploratory behaviour, but ad libitum feeding does not eliminate the motivation to perform explorative behaviour (Beattie and O’Connell, 2002; Day et al., 1995), and part of the exploration seen in ad libitum fed pigs may represent a baseline level of appetitive foraging.
3.2. Novelty

Part of the exploratory behaviour of pigs may also be controlled by curiosity. This motivation may arise when the pig discovers an unfamiliar object (inspective exploration) or when the pig searches for novelty (inquisitive exploration). As the environment in a pigpen is rather barren and unchanging, much of the exploratory behaviour expressed by pigs fed ad libitum is likely to reflect the pigs actively searching for novelty.

Pigs are willing to work to get access to a rooting material (Ladewig and Matthew, 1996; Pedersen et al., in press), and pigs will also actively search for novel stimuli (Stolba and Wood-Gush, 1980; Day et al., 1995). For instance, Wood-Gush and Vestergaard (1991) found that domestic piglets showed a preference for novel object to known objects. Furthermore, Forkman (1991) and Inglis et al. (1997) have demonstrated that animals are willing to work for food even when comparable food is at their disposal (contrafreeloading). In the wild, the sources of food of Mongolian gerbils vary randomly as regards time, place, and amount. Forkman (1991) showed that Mongolian gerbils are able to change their strategy, if their conditions change, and concluded that they may search for food in inaccessible areas to obtain information on potential sources of food, thereby reducing their risk of future starvation.

Earlier on it was assumed that in the short term the behaviour of animals is controlled by motivations relating to immediate needs, serving the satisfaction of these needs. However, the finding that animals will choose to search for (or work for) food rather than eating free food suggest that the behaviour may also be controlled by a need to obtain information on the environment in order to increase the chances of survival in the long term (Inglis et al., 1997). It is possible that the concept of “optimal foraging strategy” that predicts that according to the given circumstances animals will maximize their net energy intake (i.e. Krebs et al., 1978) should also include optimal chances of survival (Forkman, 1991). The information primacy model put forward by Inglis et al. (2001) is based upon trade offs between (a) reducing a primary need like hunger (b) the degree of effort required to do this, and (c) reducing environmental uncertainty. Animals search for food both in order to obtain food and to reduce any uncertainty associated with the particular source of food. Thus if an animal is given the choice between two food sources that contain identical food but one has associated uncertainty (e.g. the food is hidden), the latter will be preferred; but this preference will decrease with increasing hunger. It also means that working to get access to food does not represent a behavioural need, but a need to obtain information (Jensen et al., 1995; Inglis et al., 1997).

As described in the information primacy model of an exploring animal (Inglis et al., 2001), it is likely that pigs gather information until another motivation becomes sufficiently intense (hunger, tiredness) to override the motivation to explore. This means that pigs will explore and gather information as long as they have the energy to do so and as long no other motivation becomes more pronounced than the motivation to explore.

3.3. Implications for the choice of rooting materials to pigs

Pigs are motivated to explore their surroundings, even though their immediate needs are met (e.g. they have sufficient quantities of food and water) and even though they know their pigpen. The explorative behaviour may represent appetitive foraging, but it may also represent inquisitive exploration. Pigs will quickly learn if more information may be obtained by exploration. Therefore we suggest that if the material is changeable, as well as destructible, the novelty value
will be maintained. Furthermore, if the material also contains edible parts, this may stimulate appetitive foraging behaviour. Those materials that stimulate the most exploratory behaviour are most likely to prevent redirection of the behaviour towards penmates.

4. Comparing various rooting materials

4.1. The effectiveness of straw in reducing abnormal behaviour

Straw is the most studied rooting material for pigs, and the effect of other studied materials is very often compared with the effect of straw.

It has been demonstrated that straw may reduce abnormal oral behaviour directed towards penmates (Bure et al., 1983; Fraser et al., 1991; Petersen et al., 1995; Arey and Franklin, 1995; Bure et al., 1983), and allocation of straw as bedding is an important factor in the reduction of tail biting (Day et al., 2002; Guy et al., 2002a). The behavioural repertoire of 30–80 kg pigs was more varied if the animals were kept on straw-bedded floors compared with on slatted floors (Guy et al., 2002a). Furthermore, straw appeared to be more important than space as Beattie et al. (1996) found less exploratory behaviour directed towards penmates in a small pen (0.5 m² per pig) enriched with straw and peat than in a large pen (2.3 m² per pig) without any kind of enrichment. However, fighting among regrouped pigs of approximately 30 kg was not reduced by the allocation of straw (Arey and Franklin, 1995).

It is difficult to compare studies investigating the effect of various amounts of straw allocated because the circumstances and the measured parameters differ. The studies merely confirm that pigs occupy themselves with straw when it is available. It has been concluded that 200 g of straw per pig per day appears to be better than 50 g of straw per day because the increased supply of straw increased the level of exploratory behaviour directed towards straw and reduced the level of exploratory behaviour redirected towards penmates (Arey, 1993). In another study increasing the amount of straw allocated from 100 g per pig per day to 2 kg resulted in a proportional increase in straw directed behaviour and a concomitant decrease in abnormal behaviour towards penmates (Day et al., 2002). Both of the above-mentioned studies included pigs of 30–60 kg. Furthermore, Kelly et al. (2000) found that deep bedding as well as straw-flow resulted in reduced manipulation of penmates and equipment compared with the behaviour observed in a barren pen. Also 500 g of straw per day compared with no straw reduced the manipulation of penmates (Fraser et al., 1991). In an operant conditioning test (Pedersen et al., in press), the pigs were willing to work for access to an average of 1 kg of straw daily divided into rewards of 100 g. Even when the pigs had to work considerably to gain access to a reward, they were willing to do so.

It may be concluded that there are many studies that show that the allocation of straw stimulates exploratory behaviour and reduces the amount of exploratory behaviour redirected towards penmates. The studies that have investigated the effect of straw amount have shown that the more straw available, the more exploratory behaviour is directed towards the straw. However, the minimum amount of straw that will be sufficiently large to occupy the pigs and to prevent the redirection of exploratory behaviour towards penmates has not been established.

4.2. The effectiveness of various alternatives to straw in reducing abnormal behaviour

The results of studies investigating the effect of various rooting materials on exploratory behaviour directed towards the materials and abnormal behaviour directed towards penmates are
Table 1
A summary of results on the effect of different materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Behaviour</th>
<th>Effect</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peat + straw at the same time</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>↓</td>
<td>Beattie et al. (1996)</td>
</tr>
<tr>
<td></td>
<td>Aggression</td>
<td>↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exploratory behaviour directed towards materials</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Mushroom compost from a dispenser</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>↓</td>
<td>Beattie et al. (2001)</td>
</tr>
<tr>
<td></td>
<td>Tail biting</td>
<td>↓</td>
<td></td>
</tr>
<tr>
<td>Compost twice a day</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>↓</td>
<td>Bure et al. (1983)</td>
</tr>
<tr>
<td></td>
<td>Tail biting</td>
<td>↓</td>
<td></td>
</tr>
<tr>
<td>Peat + artificial udder at the same time (peat most popular)</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>↓</td>
<td>Horrell and A’Ness (1995)</td>
</tr>
<tr>
<td></td>
<td>Tail biting</td>
<td>↓</td>
<td></td>
</tr>
<tr>
<td>Straw, bark chips, and branches</td>
<td>Behavioural repertoire</td>
<td>↑</td>
<td>Haskell et al. (1996a,b)</td>
</tr>
<tr>
<td>Whole-tree chips compared to straw</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>↓</td>
<td>Long (2002)</td>
</tr>
<tr>
<td></td>
<td>Exploratory behaviour directed towards materials</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Alfalfa hay from a dispenser</td>
<td>Aggression</td>
<td>↑</td>
<td>Madsen (2001)</td>
</tr>
<tr>
<td></td>
<td>Exploratory behaviour directed towards material</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Beets</td>
<td>Exploratory behaviour directed towards equipment</td>
<td>↓</td>
<td>Arey and Maw (1995)</td>
</tr>
<tr>
<td>Straw</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>↓</td>
<td>McKinnon et al. (1989)</td>
</tr>
<tr>
<td>Deep bedding</td>
<td>Tail biting</td>
<td>↓</td>
<td>Guy et al. (2002a)</td>
</tr>
<tr>
<td>Deep bedding</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>↓</td>
<td>Kelly et al. (2000)</td>
</tr>
<tr>
<td></td>
<td>Exploratory behaviour directed towards equipment</td>
<td>↓</td>
<td></td>
</tr>
<tr>
<td>Straw (permanently or once a day)</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>↓</td>
<td>Fraser et al. (1991)</td>
</tr>
<tr>
<td>Straw flow</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>↓</td>
<td>Kelly et al. (2000)</td>
</tr>
<tr>
<td></td>
<td>Exploratory behaviour directed towards equipment</td>
<td>↓</td>
<td></td>
</tr>
<tr>
<td>Straw + beam + branches (at the age of 4 weeks)</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>↓</td>
<td>Petersen et al. (1995)</td>
</tr>
<tr>
<td></td>
<td>Tail biting</td>
<td>↓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exploratory behaviour directed towards equipment</td>
<td>↓</td>
<td></td>
</tr>
</tbody>
</table>
summarized in Table 1. Most studies have focused on a reduction of the abnormal behaviour directed towards penmates, and only a few of them have also investigated the effect on exploratory behaviour directed towards the materials.

In general, the studies demonstrate a positive effect of providing materials, in that the level of abnormal behaviour towards penmates is reduced. For instance, Beattie et al. (1996) found that the provision of straw and peat, compared with no enrichment, reduced the duration of abnormal behaviour directed towards penmates and the duration of aggression and standing inactively, while the duration of behaviours such as chewing and snout contact to the straw and peat increased concurrently.

In an experiment aiming to elucidate pigs’ space requirements, pens with a high stocking density were enriched either with chains, bars, rags, or tyres (replaced once a week) (Pearce and Paterson, 1993). In these pens pigs performed more exploratory behaviour than in pens with the same stocking density, but without enrichment. The enrichment reduced the time spent sitting inactively. However, the frequency of exploratory behaviour was not higher than in barren pens with lower stocking density, and the enrichment did not prevent the lower weight gain, which was a consequence of the high stocking density. The allocation of occupational materials was less effective in this experiment compared to the above-mentioned experiment by Beattie et al. (1996), presumably because the materials tested by Pearce and Paterson (1993) were difficult to access because of crowding and because all the materials, except the rags, were difficult to manipulate. On the contrary, straw and peat consist of small pieces that the pigs can chew into smaller parts, whereas chains, bars and tyres can be moved and maybe chewed, but not changed or destroyed by the pigs.

### Table 1 (Continued)

<table>
<thead>
<tr>
<th>Material</th>
<th>Behaviour</th>
<th>Effect</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 bucket of straw a day for 10 pigs</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>=</td>
<td>Day et al. (2002)</td>
</tr>
<tr>
<td>Straw from dispenser</td>
<td>Tail biting</td>
<td>↓</td>
<td>Petersen (1997)</td>
</tr>
<tr>
<td>Piece of wood</td>
<td>Tail biting</td>
<td>=</td>
<td>Petersen (1997)</td>
</tr>
<tr>
<td>Mobile + two balls</td>
<td>Aggression</td>
<td>↓</td>
<td>Guy et al. (2002b)</td>
</tr>
<tr>
<td>Tyres + ball + chain at the same time (chain most popular)</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>↓</td>
<td>Horrell and A’Ness (1995)</td>
</tr>
<tr>
<td>Tyres in chains</td>
<td>Aggression</td>
<td>=</td>
<td>Schaefer et al. (1990)</td>
</tr>
<tr>
<td>Rubber toys</td>
<td>Aggression</td>
<td>↓</td>
<td>Schaefer et al. (1990)</td>
</tr>
<tr>
<td>Chain + bars + rags + tyres (changed once a week)</td>
<td>Exploration</td>
<td>↑</td>
<td>Pearce and Paterson (1993)</td>
</tr>
<tr>
<td>Tethers + metal</td>
<td>Aggression</td>
<td>↓</td>
<td>Blackshaw et al. (1997)</td>
</tr>
<tr>
<td>Chains + tyres + bars</td>
<td>Fear</td>
<td>↓</td>
<td>Pearce et al. (1989)</td>
</tr>
<tr>
<td>Chains + rubber tubes</td>
<td>Exploratory behaviour redirected towards penmates</td>
<td>=</td>
<td>Hill et al. (1998)</td>
</tr>
<tr>
<td>Sugar + mineral block</td>
<td>Aggression</td>
<td>↓</td>
<td>Schaefer et al. (1990)</td>
</tr>
</tbody>
</table>

In the column at left the materials are listed. In the second column the behaviour is listed in the following order: behaviour directed towards penmates, aggression, tail biting, behaviour directed towards the material, behaviour directed towards the equipment. In the effect column, arrows indicate if the relevant behaviour has been increased or reduced, while equal signs indicate if the behaviour was unaffected. If the desired effect has been achieved, the arrows are in the left side of the column, while if the desired effect has not been achieved, the arrows are in the right side of the column.
Scott et al. (in press) investigated the exploratory behaviour of pigs housed in straw-bedded pens and in pens with fully slatted floors, respectively. They found that pigs in straw-bedded pens spent approximately twenty percent of their time in straw-directed behaviour, and that the provision of a toy with four chewable arms (made from alkathane piping) stimulated very little exploratory behaviour and without affecting the level of straw directed behaviour. Pigs in fully slatted floor pens were given either one or four of the above-mention toys, but they spent less (only approximately 1%) time on the toys and this was unaffected by the number of toys per pen. This experiment illustrates two points. Firstly, that the toy appears to be unsuitable as occupational material, which is probably due to the fact that the toy is hardly manipulable, and secondly that the amount allocated of an unsuitable occupational material is irrelevant.

There is one report of positive effects of a hardly manipulable material, however. Blackshaw et al. (1997) found that the allocation of metal and used tethers on the floor as well as suspended from the ceiling reduced aggressive behaviour in the pigs. However, this study also found that over a period of three weeks the pigs lost interest in these materials.

Several studies demonstrate that access to a rooting material reduces the level of aggression in pigs (Schaefer et al., 1990; Beattie et al., 1996; Olsen et al., 2002; Guy et al., 2002b). This is not necessarily due to a direct effect of the materials; it may also be a secondary effect of enrichment reducing the harmful behaviour directed towards penmates, and thus the causes of aggressive attack (Beattie et al., 1996). There is, however, also an example showing that the allocation of materials increases aggression. The allocation of Alfalfa hay from a dispenser (Madsen, 2001) increased aggression, presumably because Alfalfa hay is an attractive material and when allocated from a dispenser there is a lot of competition for the material.

A study investigating the time spent with the material (Feddes and Fraser, 1994) concluded that easily destructible materials attract more chewing activity than less destructible materials (Feddes and Fraser, 1994). Pigs are most attracted to open rope ends because they are easier to catch hold of, and to torn rope ends because they are easier to tear up further. Pigs are obviously attracted to being able to perform destructible chewing behaviour (Feddes and Fraser, 1994). In the majority of the studies reviewed, the allocation of materials has resulted in a reduction of abnormal behaviour directed towards penmates. However, the purpose and the circumstances have varied considerably, and therefore it is very difficult to compare the effects of the materials.

4.3. Ranking of materials

By means of preference tests, operant conditioning tests, and studies of the time spent with the materials, the preferences of pigs for different materials have been studied. Straw is included in most of those studies that attempt to rank the materials. When comparing the results of these studies, straw may be regarded as a base line material above which, or below which, the other materials may be ranked. Even if straw is allocated in various ways (unchopped, chopped, on the floor, or from a dispenser), the ranking of straw compared to other materials is fairly unambiguous (Table 2). Peat, mushroom compost, sand, sawdust, wood shavings, branches, beets, and silage rank above straw. A common feature of these materials is that they all consist of small pieces that can be chewed into smaller pieces and that may be eaten. Ranking below straw, pigs appear to prefer ropes and rags, which are destructible, to less manipulable and indestructible objects like beams, tyres, and chains.

In one of the studies the following ranking was found by means of preference testing: peat, mushroom compost, sawdust, sand, bark chips and straw (Beattie et al., 1998). The result of this study is partly supported by Van de Weerd et al. (2003) who found that after five days pigs of all
Within each column the materials tested in the same study are listed in order of priority. Thus, the materials ranking the highest are mentioned at the top. The ranking is measured in various ways, e.g., time spent with the material or the most frequent choice of material. If possible, comparable materials mentioned in different columns are listed on the same line in order that the ranking of the individual studies may be compared to each other. (a) Seventy-four different materials were included in this study, and it has not been possible to mention them all in this table.

<table>
<thead>
<tr>
<th>Study</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beattie et al. (1996)</td>
<td>Peat, mushroom compost, beard, sand, straw, paper</td>
</tr>
<tr>
<td>Pedersen et al. (2005)</td>
<td>Peat, mushroom compost, beard, sand, straw, paper</td>
</tr>
<tr>
<td>Madsen (2001)</td>
<td>Unchopped straw, unchopped straw, beet, compost</td>
</tr>
<tr>
<td>van de Weerd et al. (2002)</td>
<td>Unchopped straw, unchopped straw, beet, compost</td>
</tr>
<tr>
<td>Day et al. (2005)</td>
<td>Unchopped straw, unchopped straw, beet, compost</td>
</tr>
<tr>
<td>Ludwig and Mathew (1996)</td>
<td>Unchopped straw, unchopped straw, beet, compost</td>
</tr>
<tr>
<td>Auy and New (1995)</td>
<td>Unchopped straw, unchopped straw, beet, compost</td>
</tr>
<tr>
<td>Pedersen (2006)</td>
<td>Unchopped straw, unchopped straw, beet, compost</td>
</tr>
</tbody>
</table>

ages spent more time with compost compared to 73 other materials. By means of operant conditioning the following ranking has been demonstrated: wood shavings, sawdust, straw, chopped straw, and sand (Ladewig and Matthew, 1996). This discrepancy between the ranking of sand and straw in the studies of Beattie et al. (1998) and Ladewig and Matthew (1996) is one of the few examples of ambiguous results as regards the ranking of materials between different studies. In a more recent study using growing pigs in an operant conditioning test, in which the animals could choose to work for either straw or an alternative material, the pigs preferred peat to fir branches, and they preferred these two materials to long straw as well as chopped straw (Pedersen et al., in press). In a similar set-up where pigs could work for either peat or an alternative material they preferred maize silage, wood chip and compost to rope, seed grass hay and straw (Jensen and Pedersen, in press). In a study investigating the time spent with the materials, Horrell and A’Ness (1995) found that turf was rooted more by the pigs than peat, and that pigs chewed more on a hanging rope than on artificial dog bones and a hanging chain. In another study of Arey and Maw (1995), also focusing on the time spent with the materials, it was demonstrated that beets were more enriching than straw when measured on the reduction in equipment manipulation. Furthermore, in a study by Madsen (2001) it was demonstrated that pigs spent most time manipulating long straw on the floor and least time on wooden beams. Between these extremes, the following ranking was found: straw in a dispenser, rope suspended from the ceiling, and a piece of flexible tubing that was also suspended from the ceiling, and there were no differences as regards the time spent with these three materials. A recent experiment demonstrated that pigs used straw from a dispenser more than a rootable dispenser providing flavoured food and a manipulative dispenser providing flavoured water (Van de Weerd et al., 2006). In a Dutch study comparing various materials suspended from the ceiling (a rope, a beam, a metal chain and a pipe) during a period of 12 weeks, it was shown that the pigs spent much more time with the rope than with the other materials. No differences were found as regards how much time the pigs spent on the other three materials (Zonderland et al., 2003). Thus, beams, metal chains and pipes are less suitable as occupational materials according to this study. In a recent review on environmental enrichment Bracke et al. (2006) concluded that straw and compound materials are best, and that substrates (e.g. compost, earth, sawdust, and peat), roughage, wood, rope and rubber may be sufficient. This ranking is in conflict with the ranking based on the previous reviewed studies, which suggest that roughage, compost, peat and branches are preferred over straw (see Table 2). The conflict between Table 2 and Bracke’s ranking may be due to their choice of material classes, welfare parameters and calculation rules. Although Bracke et al. (2006) present the calculation rules as an example, they conclude from the resulting ranking.

4.4. What characterises materials that have high occupational value

On the basis of all the studies it seems that the stimulus value of a material is increased if the material is complex (Olsen et al., 2000), can be bitten (Grandin and Curtis, 1984b) or chewed (Feddes and Fraser, 1994; Fraser et al., 1991; Van de Weerd et al., 2003), is easy to manipulate (Grandin and Curtis, 1984b), is changeable (Grandin and Curtis, 1984a; Fraser et al., 1991; Feddes and Fraser, 1994; Blackshaw et al., 1997; Van de Weerd et al., 2003), and if it is edible (Young et al., 1994; Van de Weerd et al., 2003). A material will maintain its occupational value if rewards in the form of small pieces of food are available at intervals (Young et al., 1994; Haskell et al., 1996b), and in order to remain an enrichment value in the long term, the material must be rewarding beyond its novelty value (Young et al., 1994). That a material is changeable and
destructible means that it is constantly changing and thus it may continue to stimulate exploration.

5. Allocation of rooting materials

When allocating materials for enrichment, two factors must be taken into consideration: The materials must be allocated in such a way (1) that proper investigation and manipulation is possible (2) and that fighting for access to the materials is minimal.

Most studies attempting to elucidate the effect of the method of allocation are based on the allocation of straw. Thus, it has been demonstrated that, irrespective of the allocation method (e.g. allocated on the floor or by means of a dispenser), straw reduces abnormal behaviour directed towards penmates (Fraser et al., 1991; Arey, 1993; Petersen et al., 1995; Kelly et al., 2000; Guy et al., 2002a). Positive effects of straw provided in a rack (Bure et al., 1983; Bure and Koomans, 1981, Krotzl et al., 1994) have also been demonstrated. However, Madsen (2001) has shown that the allocation of straw and Alfalfa hay from a dispenser may increase aggression. It is, however, likely that this negative effect is a result of insufficient space around the dispenser, and thus it is not a consequence of the materials being unsuitable (Madsen, 2001). One study has demonstrated that weaned pigs paid more attention to suspended materials than to materials lying on the floor (Blackshaw et al., 1997), but this may be due to the materials becoming soiled when lying on the floor. As regards suspended materials Zonderland et al. (2003) found that pigs have no preference for vertical or horizontal hanging materials. The materials tested were wood, rope, chain and pipe and the result may be affected by the low changeability and destructibility of these materials. Finally, Schaefer et al. (1990) and Grandin et al. (2003) stated that occupational materials must be changed frequently and soiling of the materials must be avoided. Except for suggesting that unsoiled rooting materials should always be available for all the pigs in a pen, conclusions cannot yet be made with respect to which method to recommend for the allocation of rooting and occupational materials.

6. Conclusion

The domestic pig has a need to perform the exploratory behaviour, which is essential for the survival of its ancestor, the wild boar. The domestic pig is explorative and omnivorous, and it uses its snout to explore the environment as well as objects in the environment. If there is nothing to explore in a pigpen, the pig redirects its exploratory behaviour towards pen fixtures or penmates. The pig has a motivation to explore for food and other resources to meet its immediate needs, as well as a motivation to explore novel features within its environment and to explore for environmental change. A material stimulates the exploratory behaviour of pigs given that the material has novelty value. If the material is complex and if it is changeable as well as destructible, the novelty value will be maintained. Furthermore, if the materials contain edible parts, the foraging behaviour as well as the curiosity of the pigs will be stimulated.

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References


