The value assigned to six different rooting materials by growing pigs

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Abstract

According to EU legislation pigs must have access to rooting material, and the aim of the study was to quantify growing pigs’ preferences among six different rooting materials. The relative attractiveness of six rooting materials was assessed in an operant conditioning set-up using concurrent schedules of reinforcement. Twelve pigs were tested with all six combinations of the reference material (peat) and one of the six test materials in a balanced design. The cost of access (fixed ratio of presses per reward (FR)) to both reference material and test material was varied (reference/test: FR8/FR40, FR16/FR32, FR24/FR24, FR32/FR16, FR40/FR8). For each combination, demand functions for both materials were estimated as a function of the cost of the reference material leading to a cross point of the two demand functions. The intercept of the demand functions for the test materials differed (1.27, 0.97, 0.91, 0.64, 0.53, 0.48 (±0.14) for maize silage with straw, compost, spruce chips, seed grass hay, sisal rope and chopped straw, respectively; P < 0.001). The slopes of the demand functions for the six test materials did not differ. Furthermore, the demand functions for the reference material were not affected by test material. The cross point of the two demand functions for each of the six combinations was calculated to assess the relative attractiveness of the six test materials using the reference material as a common scaling factor. The cross points (95% confidence interval in brackets) revealed the following ranking (the lower values are the most preferred): maize silage with straw (14.2 (9.5–18.5)), spruce chips (18.0 (13.8–21.9)), compost (18.2 (13.8–22.3)), sisal rope (25.5 (21.4–29.6)), seed grass hay (27.1 (22.7–31.8)), chopped straw (28.5 (24.5–32.8)). All the tested materials were valued as much as chopped straw, but maize silage with straw, spruce chips and compost were valued higher. The results confirm that pigs prefer more complex and compound rooting materials.

Keywords: Environmental enrichment; Rooting materials; Pigs; Concurrent schedules of reinforcement; Double demand functions

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1. Introduction

Several studies have shown that straw provides an outlet for the foraging and explorative motivation of pigs and that the provision of straw reduces abnormal manipulation of pen mates (e.g. Bolhuis et al., 2005). Alternatives to straw have also been investigated, for instance peat (Beattie et al., 2001), which was found to have the same beneficial effect as straw, and which was preferred to straw (Pedersen et al., 2005). Various so-called ‘toys’ have also been suggested as rooting materials. The pig producers may prefer the toys, because they do not interfere with the slurry system, but pigs prefer chewable toys to more ‘durable’ toys (Apple and Craig, 1992). Furthermore, straw bedding (Guy et al., 2002; Van de Weerd et al., 2005, 2006) and mushroom peat (Beattie et al., 2001) are the only rooting materials that have been reported to reduce tail biting. Therefore, when new materials, including toys, are proposed as potential rooting materials to pigs, it should be thoroughly investigated if they provide an outlet for the motivation to explore in pigs.

According to new EU legislation “Pigs must have permanent access to a 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 rooting materials must enable the pigs to perform investigation and manipulation, and the literature suggests that materials that are complex, manipulative and edible (Van de Weerd et al., 2003; Olsen et al., 2000) stimulate the most investigation and manipulation. Legislation lists several examples of rooting materials, but it is not clear if they are all equally suitable for investigation and manipulation. The effects of straw are well documented (Tuyttens, 2005; Studnitz et al., in press) and we propose as a starting point that alternative rooting materials should possess at least the same stimulating properties as straw. Therefore, to establish which materials are suitable as rooting materials, the pigs’ preferences among the various rooting materials in relation to straw should be quantified.

Elasticity of demand functions has previously been used to assess the relative value of different rooting materials to pigs (Ladewig and Matthews, 1996) and more inelastic demands for wood shavings, sawdust, chopped straw and straw bedding were found compared to sand. However, Ladewig and Matthews (1996) noticed differences in the elevation of the demand function relative to the origin and suggested that when evaluating preferences among similar resources to meet the same behavioural need, it may be relevant to consider the level of consumption in addition to the elasticity. The level of consumption has no interpretation in the comparison of demand for different behavioural patterns, but it does in the comparison of different resources to stimulate the same behaviour, e.g. different rooting materials to pigs. Furthermore, when the question concerns the importance of various resources to stimulate a specific behaviour it appears relevant to introduce an element of choice. In a recent study Pedersen et al. (2005) developed a method using concurrent schedules of reinforcement to assess the strength of pigs’ preferences for different rooting materials. When animals work on concurrent schedules of reinforcement for food, or other valued resources, they adjust their efforts according to how difficult it is to get access (the workload) to either of the two resources and the quality (the value) of the two resources in relation to the underlying motivation. Based on the trade-off between workload and value we can calculate how much more they value one resource relative to the other. The validity of the method is supported by the finding that the cross point for two concurrent demand functions of two identical resources was in the theoretical midpoint, i.e. where the price of the two was equal (Pedersen et al., 2005). When using this method to assess the strength of pigs’ preferences for different rooting materials, pigs are given access to...
work for one of several alternative materials and a reference material simultaneously (Pedersen et al., 2005), and the value of the different alternative materials may be determined by comparing them to the reference material, also termed a common scaling factor (Miller, 1976). Two demand functions are estimated simultaneously, one for the reference material and one for each of the alternative materials, and the method allow a direct comparison of the different test materials, but not a comparison of the reference material to any of the test materials (Pedersen and Jensen, in press). The indirect comparison through a reference material was recently validated by Holm et al. (submitted for publication) who found the same ranking of three rooting materials in pigs using direct comparisons and using a common scaling factor.

Potential rooting materials may be categorised according to the characteristics that they possess, for instance particle size, destructibility and edibility (Van de Weerd et al., 2003). In a previous study Studnitz et al. (2004) investigated which materials pigs prefer within different categories of rooting materials (various types of wood chips, various earth-like materials, various silages mixed with straw, various dry roughages, straw in various forms and finally various pig toys). They found that pigs prefer spruce chips among the wood chips, compost among the earth-like materials and maize silage among the silages. They found no preference among materials in the categories dry roughages, straw, and toys, however, from these categories seed grass hay, sisal rope and chopped straw were the most frequently chosen. Therefore, for the present experiment the six materials spruce chips, compost, maize silage mixed with straw, seed grass hay, sisal rope and chopped straw were selected for a comparison between materials from each of the above mentioned six material categories. The aim of the present experiment was to assess the relative value of these rooting materials based on the cross point between demand functions derived using concurrent schedules of reinforcement.

2. Materials and methods

2.1. Animals and housing

2.1.1. Piglets

Sixty-six piglets (Landrace × Yorkshire × Duroc) from six litters (litter size 11 ± 1.8) were weaned at 4 weeks of age (weaning live weight 8 ± 1.5 kg) and housed with their littermates in pens (3 m × 1.65 m) with concrete (one third slatted) floor until the age of 8 weeks. During the first week after weaning the piglets were given peat (Fibrimin; Vitfoss, Denmark) enriched with micro-minerals (Cu, Fe, Mn, Zn) on the floor in the morning (2 l per pen per day). During the remaining 3 weeks they were given access to eight different rooting materials in a balanced order. The eight rooting materials were the six materials to be tested, the reference material, and straw nuts (barley straw pressed into 5 mm rolled nuts). For the weaned piglets the peat used was enriched peat, whereas in the later operant tests the peat was ordinary garden peat. Garden peat and the remaining rooting materials are described in Table 1. The eight rooting materials were given in a balanced order, one material at a time. The piglets were given spruce chips, compost, maize silage mixed with straw and sisal rope every second day and seed grass hay, chopped straw and peat every other second day from 5 to 8 weeks of age. Each pen was given 8 l of the material per allocation. The period from 8.00 to 13.00 h was divided into four periods of 75 min and the piglets had access to each material for 70 min. Before a new material was provided 5 min were available to remove the previous material and to clean the pen. At 13.00 h the material allocated last was removed and the pens were cleaned. The order of access to the four rooting materials within day was balanced in such a way that all materials were given equally as material number one, two, three and four, respectively. In each litter four pigs were randomly selected and marked for individual identification. The behaviour was video recorded from 8.00 to 13.00 h on 2 days when the piglets were 7 weeks old (observation one) and 2 days when the piglets were 8 weeks old (observation two). The behaviour of the marked piglets was recorded by instantaneous recording at 1-min interval during the first 60 min after allocation of each material. The behavioural elements recorded are
described in Table 2. However, the elements root, chew and nose were difficult to distinguish from each other in the video recordings and they were therefore grouped to a new variable termed manipulate.

2.1.2. Pigs

At 8 weeks of age three castrated male pigs were selected from each of the six litters (live weight 24 ± 3.2 kg) and moved to an experimental building where they were housed with their litter mates in home pens, which measured 1.9 m × 1.8 m and had concrete floor. In each pen food was provided in two troughs and water was available via one nipple. Both food and water were available ad libitum. Until 55 kg live weight the food contained 8.18 MJ/kg and 17% crude protein, from 55 to 75 kg live weight the food contained 7.57 MJ/kg and 16% crude protein. From 75 kg live weight this food was gradually diluted with oat bran, and from 85 kg live weight and throughout the experimental period the food contained 40% oat bran (5.56 MJ/kg and 12% crude protein).

Table 1

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>Presentation</th>
<th>Weight (kg) per 3 l (mean ± S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spruce chips</td>
<td>Chips of small trees (including trunk, branches and bark) of Norway spruce (Picea abies), and sitka spruce (Picea sitchensis) chipped 1 year from harvest</td>
<td>On floor</td>
<td>1.05 ± 0.08</td>
</tr>
<tr>
<td>Compost</td>
<td>Garden waste, which has been crushed and composted for 3 months (max. temperature 60 °C)</td>
<td>On floor</td>
<td>0.62 ± 0.02</td>
</tr>
<tr>
<td>Sisal rope</td>
<td>One meter of sisal rope (14 mm in diameter). The end of the rope was loosened (20 cm) into the three main strands lying on the floor.</td>
<td>Hung with the end of the rope (20 cm) lying on the floor.</td>
<td></td>
</tr>
<tr>
<td>Maize silage with straw</td>
<td>Maize silage mixed with barley straw (weight ratio 2:1)</td>
<td>On floor</td>
<td>0.21 ± 0.04</td>
</tr>
<tr>
<td>Peat</td>
<td>Garden peat without any plant nutrients added</td>
<td>On floor</td>
<td>0.92 ± 0.03</td>
</tr>
<tr>
<td>Seed grass hay</td>
<td>Hay from seed production of rye grass (Lolium perenne)</td>
<td>On floor</td>
<td>0.12 ± 0.01</td>
</tr>
<tr>
<td>Chopped straw</td>
<td>Barley straw, chopped to a length of 5–8 cm</td>
<td>On floor</td>
<td>0.22 ± 0.01</td>
</tr>
</tbody>
</table>

a Mean of 10 portions.

Table 2

<table>
<thead>
<tr>
<th>Recorded for piglets in home environment and for pigs during operant tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roota</td>
</tr>
<tr>
<td>Chewa</td>
</tr>
<tr>
<td>Nosea</td>
</tr>
<tr>
<td>Shake</td>
</tr>
<tr>
<td>Roll</td>
</tr>
<tr>
<td>Inactive</td>
</tr>
</tbody>
</table>

Only recorded for piglets in home environment

| Scamper | Running with bouncy movements or jumping, either up and down or while whirling around, often accompanied by rotational movements of the head |
| Aggression | Pushing with the snout/forehead upwards and downwards in the flank of another pig, or parallel press (two pigs standing side by side or front to front while pushing hard with the shoulders against each other), accompanied by bites and head knocks (thrusting sidewardly with its head against the head or body of the other pig) |

a These were grouped to a new variable ‘manipulate’ for the piglets only.
The three selected pigs from each litter were allocated as two test pigs and one companion pig, respectively. The test pigs were trained to work on concurrent schedules of reinforcement from 9 weeks old. When the pigs were 15 weeks old (live weight 60 ± 11.6 kg), the testing and the data collection started. Before testing, the test pig was walked from its home pen with its companion to the experimental room. The companion was in proximity of the test pig throughout the session to prevent any negative effect of isolation on the results (Pedersen et al., 2002). The test room contained two sets of identical double pens and two test pigs could be tested simultaneously, each of them with their companion. A wooden wall separated the two sets of pens, each of which included a test pen and an attached companion pen. Vertical tubular metal bars (15 cm between the bars) separated the work and companion pens. The test pen (2 m × 2 m) contained two operant panels, which were placed approximately 30 cm above floor level and approximately 1 m apart. The companion pens also measured 2 m × 2 m, but were without any operant panels. During the training and testing, the test animals could work by pressing either of the two panels. One panel always provided the reference peat, while the other panel provided one of the test materials. The positions of the test and the reference panels were the same for all test pigs. The companion animal was given a free reward of the same material each time the test pig earned a reward. Each time a panel was pressed, a sound as well as a light signal was given to signal a correct response. One of six different rooting materials (spruce chips, compost, maize silage with straw, seed grass hay, sisal rope and chopped straw) was available on one panel (the test panel) while the reference material peat was always available on the other panel (the reference panel).

Each reward of any of the test materials spruce chips, compost, maize silage with straw, seed grass hay, and chopped straw consisted of 3 l of that material, which was delivered onto the floor from a dispenser placed 1.5 m above floor level and proximate to from the test panel. When a reward of the test material sisal rope was given, the rope was hanging from the dispenser and 20 cm of the rope was lying on the floor (see Table 1). Each reward of the reference material peat consisted of 3 l of peat.

During the initial week of the 6 weeks training period, the fixed ratio of presses per reward (FR) was low on both panels (e.g. FR1/FR1 or FR2/FR2), but during the following weeks the workload was gradually increased and also the difference between the workload on the two panels was increased. During the final week of the 6 weeks training period the pigs worked on the five pairs of fixed ratio (FR) schedules, which were used during the actual data collection: (1) FR8 on the reference panel versus FR40 on the test panel (i.e. FR8/FR40), (2) FR16/FR32 (3) FR24/FR24 (4) FR32/FR16 and (5) FR40/FR8. The number of rewards earned in each test session was recorded on a computer using self-written software (Decker et al., 2000). Once the pig was given a reward, the panel was immediately made operational again to allow the pigs to gain a new reward as soon as they were motivated for that. Each test session lasted 50 min.

The pigs were tested in a Latin square design including six test periods. Each of these test periods lasted 12 days and was sub-divided into six 2-day periods. Each test period started with a 2-day training schedule where the workload was FR8/FR8 (not included in the subsequent analysis). Subsequently, the five pairs of FR-values were randomly distributed to the remaining five 2-day periods. The pigs were tested from Monday to Friday and all pigs were tested on all test days.

To elucidate which behavioural elements the test pigs directed towards the test materials their behaviour was recorded once during each of the six test periods. Direct observations using instantaneous recording at 1-min intervals were conducted. These observations were placed during one of the last five test days within each of the six test periods and on days with FR24/FR24 or FR16/FR32. For root, chew, nose, shake and roll (Table 2) it was noted if the behaviour was directed towards the reference material peat or any of the six test materials. At the end of the experiment the pigs were 29 weeks old and weighed 177 ± 10.4 kg.

3. Statistical analysis

3.1. Piglets’ behaviour in the home pens

For each 2-day observation and for each piglet the proportion of observations where the piglets were scored to manipulate, roll, scamper, show aggression, and being inactive was calculated for
each material. Subsequently, an average per pen was calculated for each observation and material, yielding at total of 96 observations. These data was analysed using a mixed model (Littell et al., 1996) including as fixed effects material (spruce chips, compost, maize silage with straw, seed grass hay, sisal rope, chopped straw, straw nuts, or peat) observation (one or two), and order of presentation within day (1st, 2nd, 3rd, or 4th). As random effects the model included material × pen and observation × pen. The correlation structure of the repeated observations of each pen within day was modelled as autoregressive of first order. Roll, aggression, and scamper were subjected to square root transformation to meet the assumptions of normal distribution.

3.2. Demand functions and cross points

For all six test conditions demand functions for the test material and the reference were estimated as a function of the cost of the reference material using the following model:

\[ Y_{ijklm} = \alpha_{ij} + \beta_{ij}X_{ijklm} + A_l + B_{ijk} + e_{ijklm} \]

where \( Y_{ijklm} \) is log (number of rewards obtained per test session on each panel + 1), \( \alpha_{ij} \) is the effect of the \( ij \)th test condition \((i = 6 \) test materials \((\text{spruce chips, compost, maize silage with straw, seed grass hay, sisal rope, chopped straw})\), \( j = 2 \) panels \((\text{reference, test})\)), \( \beta_{ij} \) is the regression coefficient at the \( ij \)th test condition, \( A_l \) is the random effect of the \( l \)th test pig \((l = 1, 2, \ldots, 12)\), \( B_{ijk} \) is the random effect of the \( ij \)th condition in the \( k \)th period \((k = 1, 2, 3, 4, 5, 6)\), \( X_{ijklm} \) is FR on the reference panel of the \( ij \)th condition in the \( k \)th period and the \( l \)th test pig \((m = 8, 16, 24, 32, \text{and 40})\), and \( e_{ijklm} \) is the residual error. \( A_l, B_{ijk} \) and \( e_{ijklm} \) are assumed normally distributed. The correlation structure of the repeated observations of each pen within day was modelled as autoregressive of first order. The estimates of \( \alpha_{ij} \) and \( \beta_{ij} \) from the above model and their corresponding variance matrix were used to estimate the cross points between the two lines. The cross points were found as the solution to linear equations in the parameters, and exact confidence intervals were found using the approach described in Box and Hunter (1954). See also Pedersen et al. (2005).

3.3. Behaviour directed towards the materials during the operant tests

For each day of observation and for each pig the number of observations where chew, root, nose, shake or roll was directed to either the test material or the reference material was calculated. Also the sum of oral activities (sum of number of observations with chew, root, nose, shake and roll) directed towards the test material and the reference material was calculated. For both the test and the reference material each of the activities chew, root, nose and shake was calculated as a percentage of the sum of oral activity with that material. As each pig was observed with each material there were 72 observations for test material and reference material, respectively. Data for chew and root were analysed using a mixed model (Littell et al., 1996) including as fixed effects material (maize silage with straw, spruce chips, compost, seed grass hay, sisal rope, chopped straw) and period (1, 2, 3, 4, 5, 6). As random effects the model included animal and material × period. The correlation structure of the repeated observations of each pig was modelled as autoregressive of first order. Data for nose were not normally distributed and were analysed by Friedman test (Siegel and Castellan, 1988). There were no observations of roll. Shake was only observed directed towards seed grass hay or sisal rope, and this variable was transformed into a binary variable, but not subjected to further analysis due to few observations.

The number of 1-min scans where the pigs were active with the test material per reward earned of the test material, as well as the number of 1-min scans were the pig were active with the
Due to five occasions where the test pig did not earn a reward on one of the panels, this analysis included 68 and 67 observations for test material and reference material, respectively. These variables were subjected to analysis using a mixed model (Littell et al., 1996) including as fixed effects material (maize silage with straw, spruce chips, compost, seed grass hay, sisal rope, chopped straw) and period (1, 2, 3, 4, 5, 6). As random effects the model included animal and material × period. The correlation structure of the repeated observations of each pig was modelled as autoregressive of first order.

In the data presentation, different superscripts indicate that estimated means are significantly different ($P < 0.05$).

4. Results

4.1. Piglets’ behaviour in the home pens

The behaviour of the piglets in the home pens is shown in Table 3. The piglets directed more manipulation to the materials, and were less inactive, when the material was spruce chips, compost, maize silage with straw and peat compared to seed grass hay, sisal rope, chopped straw and straw nuts. The piglets rolled onto peat and sisal rope more than any of the remaining materials. The piglets fought more when peat, sisal rope, spruce chips and chopped straw were available compared to when any of the remaining materials were available. Finally, sisal rope and spruce chips stimulated more scamper than any of the remaining materials.

The piglets manipulated the materials more in the first compared to the second period of observation (26.82 (±1.06) min/h versus 21.53 (±1.06) min/h; $F_{1,5} = 18.61; P < 0.01$), and order of presentation within day affected the level of inactivity (24.48a (±2.41), 24.74a (±2.33), 26.00a (±2.37), and 33.04b (±2.30) min/h for 1st, 2nd, 3rd, and 4th order, respectively, $F_{3,39} = 8.99; P < 0.001$).

4.2. Demand functions and cross points

The cross points between the demand curves for the various test materials and their corresponding reference functions are shown in Fig. 1. Test material affected the cross point significantly (Table 4). The cross points for maize silage with straw, spruce chips and compost were significantly lower than those for seed grass hay and chopped straw. The cross point for maize silage with straw was also lower than that for sisal rope, while the cross points for spruce chips, compost and sisal rope did not differ significantly.

Test material affected the intercepts of the demand functions for the test materials ($F_{11,199} = 37.64; P < 0.001$; Table 4). None of the reference curves had significantly different intercepts. None of the reference curves had significantly different slopes, nor had any of the test curves.

4.3. Behaviour directed towards the materials during the operant tests

The percentage of observations where the test materials, sisal rope, spruce chips and seed grass hay were chewed was higher than for maize silage with straw and chopped straw, while percentage of observations where compost were chewed was intermediate (65.4a, 57.5a, 57.5a, 53.5ab, 40.1b, 39.8b (all ± 6.97) percentage of activity for sisal rope, spruce chips, seed grass hay,
Table 3
Behaviour of the piglets directed towards the different rooting materials in home pen

<table>
<thead>
<tr>
<th></th>
<th>Maize silage/straw</th>
<th>Spruce chips</th>
<th>Compost</th>
<th>Peat</th>
<th>Sisal rope</th>
<th>Seed grass hay</th>
<th>Chopped straw</th>
<th>Straw nuts</th>
<th>F&lt;sub&gt;7,40&lt;/sub&gt;</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manipulate</td>
<td>30.8 ± 2.44</td>
<td>30.6 ± 2.48</td>
<td>34.6 ± 2.46</td>
<td>32.1 ± 2.46</td>
<td>19.6 b ± 2.47</td>
<td>14.5 b ± 2.47</td>
<td>16.4 b ± 2.48</td>
<td>14.8 b ± 2.46</td>
<td>10.67</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Roll&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.23 b ± 0.11</td>
<td>0.29 b ± 0.12</td>
<td>0.42 b ± 0.11</td>
<td>0.85 a ± 0.12</td>
<td>0.72 a ± 0.12</td>
<td>0.34 b ± 0.12</td>
<td>0.38 b ± 0.12</td>
<td></td>
<td>0.03 c ± 0.11</td>
<td>5.53</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.07)</td>
<td>(0.17)</td>
<td>(0.71)</td>
<td>(0.52)</td>
<td>(0.12)</td>
<td>(0.14)</td>
<td></td>
<td></td>
<td>(0.01)</td>
</tr>
<tr>
<td>Aggression&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.39 d ± 0.17</td>
<td>0.92 ab ± 0.17</td>
<td>0.81 bc ± 0.17</td>
<td>1.34 a ± 0.17</td>
<td>0.94 ab ± 0.17</td>
<td>0.70 bc ± 0.17</td>
<td>0.94 ab ± 0.17</td>
<td>0.51 cd ± 0.17</td>
<td>3.48</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.85)</td>
<td>(0.66)</td>
<td>(1.80)</td>
<td>(0.88)</td>
<td>(0.49)</td>
<td>(0.88)</td>
<td></td>
<td></td>
<td>(0.26)</td>
</tr>
<tr>
<td>Scamper&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.22 c ± 0.23</td>
<td>1.21 a ± 0.23</td>
<td>0.48 bc ± 0.24</td>
<td>0.72 b ± 0.23</td>
<td>1.22 a ± 0.23</td>
<td>0.67 bc ± 0.23</td>
<td>0.38 bc ± 0.23</td>
<td>0.37 bc ± 0.24</td>
<td>2.79</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(1.46)</td>
<td>(0.22)</td>
<td>(0.52)</td>
<td>(1.49)</td>
<td>(0.44)</td>
<td>(0.14)</td>
<td></td>
<td></td>
<td>(0.14)</td>
</tr>
<tr>
<td>Inactive</td>
<td>15.6 d ± 3.10</td>
<td>19.3 d ± 3.01</td>
<td>21.2 d ± 2.96</td>
<td>19.1 d ± 3.11</td>
<td>30.7 c ± 3.19</td>
<td>40.1 a ± 3.19</td>
<td>31.7 c ± 3.07</td>
<td>38.8 ab ± 2.96</td>
<td>10.43</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Out of 12 observations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Shake</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

Within row means with different letters (a, b, c, d) are significantly different (P < 0.05).

<sup>a</sup> Number of 1-min scans per hour.

<sup>b</sup> Roll, aggression and scamper were analysed following square root transformation, and the values in parenthesis are back calculated means as square of the estimates.
compost, maize silage with straw and chopped straw; $F_{5,20} = 2.78; P < 0.05$). Maize silage with straw was rooted the most, while sisal rope was rooted the least (54.7a, 37.0b, 33.2bc, 26.1bc, 20.1bc, 15.6c (all ± 5.88) percentage of activity for maize silage with straw, compost, chopped straw, seed grass hay, spruce chips, and sisal rope, respectively, $F_{5,20} = 6.83; P < 0.001$). No significant difference was found in the percentage of nosing directed to the test materials, but only seed grass hay and sisal rope were shaken. The test material did not affect the percentage of time spent chewing, rooting or nosing the reference material peat.

The average activity (sum of chew, root, nose and shake) directed towards each of the test materials per reward of test material earned, as well as the activity directed towards the reference material per reward of the reference earned, is shown in Table 5. Pigs directed most activity towards the test materials maize silage, spruce chips, compost, seed grass hay and least activity towards chopped straw while sisal rope was intermediate ($F_{5,19} = 2.83; P < 0.05$; Table 5). The pigs were least active with the reference material when the test materials were maize silage with straw and most active when the test material was sisal rope, while the remaining were intermediate ($F_{5,19} = 4.78; P < 0.01$; Table 5).

### 5. Discussion

Based on the cross points, the pigs valued maize silage with straw, spruce chips and compost higher than seed grass hay and chopped straw.

The quantification of the relative value of the test materials was made through the reference by comparing the cross points, which are the price ratio where the pigs take an equal amount of the test and the reference material. The stronger the preference, the lower the cross point (Pedersen et al., 2005; Sørensen et al., 2004). The values of the cross points illustrate how much the pigs will pay for the different materials in relation to the reference material. For instance, the pigs paid 2.43 (cross point price ratio 34/14) times more per reward for maize silage with straw compared to the reference, while they paid 0.65 (cross point price ratio 19/29) times more for chopped straw relative to the reference. One way of looking at the relative value of maize silage with straw to chopped straw is to compare the two test materials via the reference; maize silage with straw is valued 3.7 (2.43/0.65) times more than chopped straw. In the same way, the pigs paid 1.67 (cross

![Graph](image-url)
<table>
<thead>
<tr>
<th></th>
<th>Maize silage/straw</th>
<th>Spruce chips</th>
<th>Compost</th>
<th>Sisal rope</th>
<th>Seed grass hay</th>
<th>Chopped straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross point</td>
<td>14.2 a (9.5–18.5)</td>
<td>18.0 ab (13.8–21.9)</td>
<td>18.2 ab (13.8–22.3)</td>
<td>25.5 bc (21.4–29.6)</td>
<td>27.1 c (22.7–31.8)</td>
<td>28.5 c (24.5–32.8)</td>
</tr>
<tr>
<td>Intercept</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td>1.27 a ± 0.14</td>
<td>0.91 b ± 0.14</td>
<td>0.97 ab ± 0.14</td>
<td>0.53 c ± 0.14</td>
<td>0.64 bc ± 0.14</td>
<td>0.48 c ± 0.14</td>
</tr>
<tr>
<td>Reference</td>
<td>2.15 ± 0.14</td>
<td>2.10 ± 0.14</td>
<td>2.11 ± 0.14</td>
<td>2.17 ± 0.14</td>
<td>2.21 ± 0.14</td>
<td>2.31 ± 0.14</td>
</tr>
<tr>
<td>Slope</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td>0.027 ± 0.003</td>
<td>0.030 ± 0.003</td>
<td>0.029 ± 0.003</td>
<td>0.035 ± 0.003</td>
<td>0.028 ± 0.003</td>
<td>0.031 ± 0.003</td>
</tr>
<tr>
<td>Reference</td>
<td>−0.035 ± 0.003</td>
<td>−0.036 ± 0.003</td>
<td>−0.034 ± 0.003</td>
<td>−0.029 ± 0.003</td>
<td>−0.030 ± 0.003</td>
<td>−0.034 ± 0.003</td>
</tr>
</tbody>
</table>

The estimated cross points are given with 95% confidence intervals in brackets. The estimated mean intercepts and slopes are given with ± S.E.M. Within row means with different letters (a, b, c) are significantly different ($P < 0.05$).
Table 5
Activity with reference and test material

<table>
<thead>
<tr>
<th></th>
<th>Maize silage/straw</th>
<th>Spruce chips</th>
<th>Compost</th>
<th>Sisal rope</th>
<th>Seed grass hay</th>
<th>Chopped straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency/reward (mean ± S.E.M.)$^a$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity with test material per reward</td>
<td>2.90 a ± 0.24</td>
<td>3.16 a ± 0.27</td>
<td>3.17 a ± 0.24</td>
<td>2.58 ab ± 0.24</td>
<td>3.08 a ± 0.24</td>
<td>2.09 b ± 0.24</td>
</tr>
<tr>
<td>Activity with reference material per reward</td>
<td>2.35 c ± 0.18</td>
<td>2.82 bc ± 0.17</td>
<td>2.96 ab ± 0.20</td>
<td>3.33 a ± 0.17</td>
<td>2.88 ab ± 0.17</td>
<td>2.94 ab ± 0.17</td>
</tr>
</tbody>
</table>

Within rows means with different letters are significantly different ($P < 0.05$).

$^a$ Number of 1-min scans per reward period.
point price ratio 30/18) times more per reward for compost compared to the reference. Thus the results suggest that compost is valued 2.6 (1.67/0.65) times more than chopped straw.

In Section 1 we suggested that straw should be used as a yardstick for those materials that are proposed as alternative rooting materials and that it should be established if alternative rooting materials are as preferred by pigs as straw. An equal preference would signify that the material possesses the same stimulating properties as straw. The present results suggest that pigs value all the tested materials either equally to straw, or higher than straw, and based on how the pigs worked during the operant test, all the tested materials may be used as alternative rooting materials to straw. Three of the tested materials were valued higher than straw by the pigs. These materials were maize silage with straw, compost, and spruce chips. Van de Weerd et al. (2003) investigated a range of rooting materials and found that those materials that could maintain pigs’ attention over the longest period of time were characterised by being ingestible, destructible, deformable, chewable, odorous and to some extent rootable. We suggest that the maize silage with straw, compost and spruce chips have a larger capacity to stimulate extended exploration in pigs compared to straw because they possess higher qualities of one or more of those characteristics. For instance, the maize silage is more ingestible and the compost may be more chewable and odorous than chopped straw. It may be argued that those materials that are more complex and compound have a larger capacity to stimulate extended explorative behaviour than a more homogenous material, such as straw. This does not mean that straw is not a good rooting material; it just means that other materials may be better.

A methodological issue is of the reward size. The reward size of all types of rooting material, except sisal rope, was 3 l, and thus the weight per reward varied considerably between materials. In a previous study Pedersen et al. (2005) gave 100 g of dried material per reward, and one could argue that a constant weight and not a constant volume should be given. However, for the material investigated in the present experiment using a constant weight would have resulted in a very large difference in volume. Our choice of equal volume instead of equal weight of the material was based on the assessment that an equal volume, more that equal weight, is important for how the pigs experiences the size of the reward. Furthermore, it may be argued that size of reward was also controlled by the fixed reward duration of 3 min in the present experiment, as well as previous experiments (Holm et al., submitted for publication).

We recorded the separate elements of exploratory behaviour that the pigs directed towards each of the six different materials during the operant tests, and investigated if there was any relation between the value of the materials and the behavioural elements that the pigs directed towards them for the largest proportion of time. However, we found no such relationship. All materials were mainly rooted and chewed, which corresponds well to the suggestion that good rooting materials are ingestible, destructible and deformable (Van de Weerd et al., 2003). Therefore, it appears more appropriate to focus on the ability of the materials to stimulate and maintain exploration, rather than to focus on their ability to stimulate specific elements of exploratory behaviour.

During 3 weeks after weaning the experimental piglets were housed with their littermates and given access to the tested materials (plus enriched peat and straw nuts) in a balanced manner. This was done to ensure that the pigs had equally early experience with all materials, and to avoid the risk of any prior experience affecting the preferences in the operant tests. When we looked at the piglets’ behaviour directed towards the various materials we found that they spent more time manipulating maize silage with straw, compost, spruce chips and peat compared to the remaining materials. This indicates that those materials that stimulated the most manipulation in the piglets’ home pens were also the materials valued the most in the operant tests. However, there was one
exception. Based on the cross point, the sisal rope was not valued less than spruce chips and compost. Thus the amount of behaviour directed to the materials by the weaned piglets in the home pen does not appear to explain fully the preferences in the operant test.

Sisal rope is made from natural fibres and it is destructible. In the present experiment it had been made as attractive as possible by unbinding the end and by leaving 20 cm lying along the floor and by always providing a fresh rope for each reward. The discrepancy between the results of the cross point analysis and the activity of the piglets may be due to accessibility of the sisal rope. Whereas the piglets had to share one rope among 11 animals, the test pigs had sole access during the operant tests. The operant tests clearly show that the sisal rope possesses a value for exploration, but this must be seen in the light of ample access during the tests. Such good access will be difficult to obtain in pens where there are several pigs, and thus the sisal rope may not have the same effect as straw in a practical setting.

According to new EU legislation there must be “a sufficient quantity of material to enable proper investigation and manipulation activities”. The significance of the quantity of materials allocated is evident from Van de Weerd et al. (2006), where straw bedding was manipulated more than straw in a rack by growing pigs, and from Kelly et al. (2000) where weaned piglets on straw bedding spent more time on straw directed behaviour than pigs in straw-flow pens (50 g straw/pig/day). In the present study we have not attempted to estimate what constitutes a sufficient quantity.

The piglets performed more scamper, which is locomotor play behaviour, with the sisal rope and the spruce chips. Play behaviour is an expression of positive emotions. It is also related to exploration and may be seen as a reaction to novelty (Wood-Gush and Vestergaard, 1991). However, all the presented materials were equally novel. The sisal rope and the spruce chips are larger objects than the remaining rooting materials and this may be why they stimulated more play behaviour. However, the finding that some materials stimulate play behaviour does not necessarily make them good rooting materials. Familiarity reduces a materials’ ability to stimulate manipulation as well as play behaviour. However, if novelty is inherent in a material, due to destructibility and flexibility, then this material may be a good potential rooting material that may stimulate exploration for a long time (Studnitz et al., in press).

Aggression among the piglets was seen most when peat, spruce chips, sisal rope and straw were offered, while very little aggression was seen when maize silage with straw and straw nuts were offered. Some aggression may be related to the rolling onto the material, because this makes the material unavailable to the others. The piglets rolled more onto peat and sisal rope. The sisal rope was shaken in all observations while this was only rarely seen for any other material. This may have been an attempt to loosen the rope to further make it accessible for manipulation or to get it down on the floor.

In conclusion, all the tested materials were valued as much as chopped straw, but maize silage mixed with straw, spruce chips and compost were valued significantly higher. These more-valued materials appear to have a larger capacity to stimulate exploration in pigs than straw and this supports previous findings that rooting materials that are complex and compound have a larger capacity to stimulate extended explorative behaviour.

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References


