

Annotated Bibliographies:

I have organized my articles based on the following topic questions: “What is exploratory behaviour and its context in pigs?”, “What is the function of exploratory behaviour in pigs?”, “How does novelty and habituation influence exploratory behaviour in pigs?”, and “How does straw enrichment influence exploratory behaviour in pigs?”

What is exploratory behaviour and its context in pigs?

Studnitz, M., Jensen, M. B., & Pedersen, L. J. (2007). Why do pigs root and in what will they root?: A review on the exploratory behaviour of pigs in relation to environmental enrichment. *Applied Animal Behaviour Science*, 107(3), 183–197.
<https://doi.org/10.1016/j.applanim.2006.11.013>

Summary:

European legislation says pigs must be provided enough suitable material to enable exploration, but what makes material suitable? This review attempts to answer this question by comparing the effects of various rooting materials on the behaviour and welfare of pigs in relation to natural pig behaviour and current motivational theory.

Under natural conditions pigs spend considerable time exploring their environment in search of food. Exploratory behaviour includes rooting, sniffing, biting, and chewing both edible and inedible objects and materials. Pigs explore to satisfy a behavioural need, as suggested by the redirection of unfulfilled exploratory behaviour towards pen-mates when housed in barren pens. Pigs are motivated to explore to meet their immediate needs, as well as by curiosity to explore novel features and to search for novelty. Exploratory behaviour in pigs increases with hunger, but unrestricted feeding does not eliminate it. Based on this information they suggest rooting materials be changeable and destructible to sustain novelty and contain edible parts to encourage appetitive foraging.

The studies suggest straw stimulates exploratory behaviour and reduces abnormal behaviour. However, they indicate the minimum amount of straw needed is unknown. The studies reviewed used various methods to determine the preference of pigs. Most used straw as a base line against which other materials were ranked. They suggest peat, mushroom compost, sand, sawdust, wood shavings, branches, beets, and silage (destructible and edible) rank above straw (however some ambiguity between studies); and ranking below straw, pigs preferred ropes and rags (destructible) to objects like beams, tires, and chains (less manipulable and indestructible). They also indicated the best material allocation method could not be concluded.

Emily Hickle
30016985

They conclude a material should have novelty to stimulate exploration and to maintain novelty it should be complex, changeable, and destructible; if it contains edible parts, curiosity will be heightened and foraging stimulated.

Contribution:

I selected this review because it advances knowledge by interpreting primary sources that explore the effects of different materials on the behaviour and welfare of pigs, while also taking into consideration natural pig behaviour and current motivational theory. This allowed the authors to investigate the question: what characteristics rooting materials should have to stimulate sustained exploration in pigs? I also selected this review because it provides a summary of why pigs explore, and it gives me an understanding of how straw ranks against other rooting materials.

Kittawornrat, A., & Zimmerman, J. J. (2011). Toward a better understanding of pig behavior and pig welfare. *Animal Health Research Reviews*, 12(1), 25–32.

<https://doi.org/10.1017/S1466252310000174>

Summary:

The objective of this review was to improve understanding of pig behaviour and welfare by reviewing the basic sensory and behavioural characteristics of pigs.

Pigs have panoramic vision and can see over a 310-degree angle. The pig retina contains two types of cones with peak sensitivity at about 439nm (indigo) and 556nm (green-yellow). From this it is inferred that pigs can discriminate between some colours, but there is little information on how pigs perceive colour and even less on how colour impacts behaviour.

A pig tongue, epiglottis and soft palate are covered in taste papillae containing high numbers of taste buds. Their taste buds allow for sensing of sour, sweet, umami, and bitter. Pigs prefer sweet, meaty, and cheese flavours and reject bitter foods.

Pigs have a very sensitive sense of smell and use a range of olfactory signals in their natural behaviour. However, pig behaviour and stress in response to odours has not been well established.

Pigs can detect sound between 42Hz and 40.5kHz with the highest sensitivity between 250Hz and 16kHz. They can determine the spatial location of sounds based on the difference in time it takes sound to reach each ear. Effects of music on behaviour and welfare is under-investigated and experiments that have been done have conflicting results.

Emily Hickle
30016985

Welfare issues arise when a pig's instinctual behaviour is hindered potentially causing behavioural impulses to be inappropriately expressed. Domestic pigs, despite being provided basic necessities, still express exploratory behaviours. Enrichment objects suitable for rooting and chewing may offer a stimulus for exploratory behaviours and result in a reduction of adverse behaviours.

This review indicates that much is still not known or understood about the sensory modalities of pigs and their impact on behaviour, something this article suggests is integral to addressing pig welfare concerns.

Contribution:

This article advances knowledge by describing what is known about the basic sensory modalities and behavioural aspects of pigs. This article is important because it indicates the importance of understanding the biology behind pig behaviour and welfare. I included this article in my literature review because it describes the sensory modalities of pigs.

What is the function of exploratory behaviour in pigs?

Day, J. E. L., Kyriazakis, I., & Lawrence, A. B. (1996). An investigation into the causation of chewing behaviour in growing pigs: The role of exploration and feeding motivation. *Applied Animal Behaviour Science*, 48(1), 47–59. [https://doi.org/10.1016/0168-1591\(95\)01022-X](https://doi.org/10.1016/0168-1591(95)01022-X)

Summary:

Chewing occurs extensively during both foraging and exploratory activity of wild and feral pigs. Domestic pigs also spend considerable time chewing substrates in their environment. However, it is unclear whether chewing indicates feeding motivation, exploratory motivation, or a combination of both. It has been suggested animals encounter information while exploring which they can learn from and use to make later foraging decisions. The objective of this study was to test the hypothesis that initial exploratory chewing of an unknown substrate may lead to nutritional information being obtained, altering future foraging behaviour.

This study consisted of two replicates of 18 pigs each. Each pig was housed individually, maintained at one of two feeding levels, and presented with two perforated tubes, a control-tube filled with water and a treatment-tube. The treatment-tube contained either a sucrose solution providing a sweet taste and a source of digestible energy, a saccharine solution providing only a sweet taste, or water. The feeding-levels were either high fed with digestible energy requirements met or low fed with digestible energy restricted. Behaviour was observed for ten days using scan sampling with a five-minute interval.

The control-tube was chewed throughout the experiment at a low level and was not affected by stimulus or feeding-level. This is believed to be the exploratory behaviour correlated with ongoing information gathering. The level of tube chewing was higher in the sucrose and saccharine treatments, however, tube chewing behaviour was only significantly affected by time in low fed pigs that encountered sucrose. Significance was reached after 6.5h of experience and this effect persisted and strengthened for the rest of the experiment. These results suggest growing pigs can gain nutritional feedback during exploratory chewing, and when this nutritional feedback is relevant to a specific nutritional deficiency, foraging behaviour may be adjusted to better meet these needs.

Contribution:

This study is important and advances knowledge because it suggests domesticated growing pigs can gain nutritional information during exploratory chewing, and when this nutritional feedback is relevant to a specific nutritional deficiency within the individual, a suitable foraging behaviour may be adopted. I included this article in my literature review because it discusses a possible function of exploratory behaviour as a way for pigs to collect nutritional information from their environment that they can use to develop more effective foraging strategies to meet their nutritional needs, suggesting learning may be occurring.

How does novelty and habituation influence exploratory behaviour in pigs?

Trickett, S. L., Guy, J. H., & Edwards, S. A. (2009). The role of novelty in environmental enrichment for the weaned pig. *Applied Animal Behaviour Science*, 116(1), 45–51.

<https://doi.org/10.1016/j.applanim.2008.07.007>

Summary:

Pigs can habituate quickly to objects, reducing their effectiveness in stimulating exploration. Novelty of an object is a key property to stimulate exploration as it is considered intrinsically rewarding to pigs. Novelty can be achieved by replacing familiar objects with new ones, but little is known about how long a pig can remember an object. The first objective was to assess the effects of habituation on two environmental enrichment objects and determine whether alternating the provision of the objects would increase novelty. The second objective was to determine if the relative attractiveness of each object when given simultaneously was the same as when presented individually and if combining enrichment objects had additive or subtractive effects on object-directed behaviour.

This study tested five four-week long treatments: (R) continuous access to suspended rope (replaced every two weeks), (W) continuous access to a wood block (washed daily), weekly alternation of wood block and rope starting with (R/W) rope or (W/R) wood, and (R+W) simultaneous access to rope and wood block. Each treatment had five replicates of 10 pigs each. Behaviour was observed using timed scan samples.

When wood and rope were offered simultaneously, the effect was additive, suggesting that providing a variety of objects increases the amount of time spent in object interaction. Wood and rope interaction decreased within the first week after introduction in all treatments, suggesting habituation occurred but increasing age of the pigs may have also contributed. In the R/W and W/R treatments, when rope and wood were added for a second time, object interaction was always lower than when the object was initially added, suggesting the pigs still remembered the objects. In treatments R and R+W, when the rope was replaced in week 3, object interaction increased, indicating even limited novelty was important to maintaining pig's attention.

Contribution:

This article is important because it brings up several crucial considerations for the delivery of enrichment. This article advances knowledge because it suggests the rotation of two objects increased novelty but did not prevent habituation. Therefore, they indicate a greater understanding of memory, recognition, and habituation in pigs are needed to design effective enrichment strategies. I included this article in my literature review because it discusses how novelty and habituation influences exploratory behaviour in pigs.

Emily Hickle
30016985

Kauselmann, K., Schrader, L., Glitz, B., Gallmann, E., Schrade, H., & Krause, E. T. (2021). Tasty straw pellets – exploration of flavoured rooting material by pigs. *Animal*, 15(6), 100239. <https://doi.org/10.1016/j.animal.2021.100239>

Summary:

Pigs have a highly developed sense of smell. They prefer sweet and umami flavours while they reject bitter flavours. The objective of this study was to determine the effect of straw pellets with different flavours on pig exploration. They hypothesized that pigs would prefer certain flavours resulting in higher exploration durations for those flavours.

In this experiment 192 pigs were tested in two successive replicates. At weaning each pig was equipped with RFID tags (radiofrequency tags). Pigs were divided into four pens (24 pigs per pen) for seven weeks during rearing and then eight pens (12 pigs per pen) for eleven weeks during fattening. The flavours tested were synthetic fried onion, strawberry, vanilla, almond, and ginger. Pellets wetted with water were the control. For every pen each flavour was switched weekly. The pellets were provided via a dispenser fitted with an RFID antenna to measure exploration duration at the feeder. Tail lengths and tail injuries were also ranked weekly.

Rearing pigs had significantly higher exploration durations for pellets flavoured with fried onion and almond. Fried onion can be ascribed to umami and pigs are known to adapt their feed intake to their nutritional needs, so the nutty taste of the almond flavour may have been associated with high fat content and high nutritional value. Fattening pigs had significantly higher exploration durations when strawberry flavoured pellets or control pellets were offered. Strawberries are sweet and the preference for unflavoured pellets suggests the natural flavour and odour of straw is attractive.

Overall exploration durations remained constant from rearing to fattening, suggesting the weekly change of flavours was more important than offering a certain flavour for maintaining high exploration durations. Mean exploration duration during fattening did not differ from rearing, suggesting the five weeks between reapplication of flavours was sufficient to prevent habituation.

Contribution:

This study is important because it provides new insights on ways to increase the attractiveness of exploration materials for rearing and fattening pigs by using flavourings. It advances knowledge by suggesting the changing of flavours rather than a specific kind of flavour may be crucial to maintaining high exploration in pigs. Furthermore, it suggests the provision of straw pellets with weekly alternating flavours may be a way to offer exploration material that remains attractive over a sustained period. I included this article in my literature review because it discusses how smell, taste, and habituation can affect exploratory behaviour.

Emily Hickle
30016985

How does straw enrichment influence exploratory behaviour in pigs?

Fraser, D., Phillips, P. A., Thompson, B. K., & Tennessen, T. (1991). Effect of straw on the behaviour of growing pigs. *Applied Animal Behaviour Science*, 30(3), 307–318.

[https://doi.org/10.1016/0168-1591\(91\)90135-K](https://doi.org/10.1016/0168-1591(91)90135-K)

Summary:

For sows, straw is believed to improve thermal comfort, provide gut filling when diet is restricted, and stimulate and facilitate exploratory behaviours. However, growing-finishing pigs are often fed without restriction and if thermal comfort is fulfilled, the exploratory function of straw is the major potential benefit remaining. The objective of this study was to identify the effects of straw on growing pig behavior where straw was not needed for feeding or comfort. They conducted two experiments to broaden the applicability of their findings. Direct observations using one-zero sampling and time-lapse video recording were used to measure the effects of straw on various behaviors, including rooting and chewing.

In Experiment 1, pigs approximately seven-weeks-old were housed with or without deep straw bedding. Ten replicates were completed, each consisting of two groups of three pigs. There were no major differences between the treatments in overall activity, but pigs with straw performed less rooting and chewing of pen-mates and chewed the environment less.

In Experiment 2, ten-week-old pigs were housed with or without straw provided daily from a rack. Four replicates were completed, each consisting of two groups of eight pigs. Pigs with straw racks were significantly more active, and rooted pen-mates and chewed the walls significantly less in the afternoon when straw was added. This was presumably due to the supply of straw from the previous day being exhausted by morning. Increased biting unrelated to feeding was also observed, often involving disputes over fresh straw.

Their results suggest the main function of straw, when adequate space, feed, and thermal comfort is provided, is to stimulate and satisfy exploratory behaviours in growing pigs and thus curb redirection of these behaviours towards pen-mates. A question raised is whether the provision of other suitable objects might achieve similar results as straw?

Contribution:

Previous studies reported effects of straw on the behaviour of growing pigs, including reduced abnormal oral behaviours directed at pen-mates. However, these studies largely confounded straw with other variables. Therefore, this study advances knowledge because it suggests that with adequate space, feed, and comfort, the primary purpose of straw is to provide a stimulus and outlet for exploratory behaviours in growing pigs. I included this article in my literature review because it provides a foundation for understanding how straw affects pig exploratory behaviour, and has been cited by many other articles I am interested in.

Emily Hickle
30016985

Zwicker, B., Gyga, L., Wechsler, B., & Weber, R. (2012). Influence of the accessibility of straw in racks on exploratory behaviour in finishing pigs. *Livestock Science*, 148(1), 67–73.
<https://doi.org/10.1016/j.livsci.2012.05.008>

Summary:

Pigs may experience social competition, aggression, or restlessness when accessibility to an enrichment object or material is limited. Therefore, the objective of this study was to determine the effect of accessibility of straw in racks on exploratory behaviour and aggression (measured as displacements by pushing or biting). They hypothesized as the number of racks increased the number of pigs exploring the straw in the racks and on the floor would increase while the rate of displacements would decrease.

Accessibility was varied by providing either one, three, six, or eight straw racks. Each group consisting of 27 pigs was exposed to each treatment for three-weeks. Behaviour was observed on day 2 and day 18 of each three-week period. Using ten-minute scan sampling, the number of pigs exploring the racks and straw that had fallen onto the floor was recorded. Displacements of pen-mates from the racks was continuously recorded between scans.

The proportion of pigs exploring the racks and straw on the floor increased with the number of racks provided, in accordance with their hypothesis. The proportion of pigs exploring straw on the floor was three to four times higher than the proportion of pigs exploring the racks, potentially because straw on the floor was spread over a larger area and thus more accessible. Pigs explored in a biphasic pattern with peaks in the morning and afternoon, which is considered typical. The proportion of pigs showing exploratory behaviour for the six and eight rack treatments at these times was almost twice as high as the one rack treatment, emphasizing the need for sufficient access to enrichment. Straw racks maintained the pigs' interest throughout the three-week periods, suggesting habituation had not occurred. Lastly, the rate of displacements decreased, as the number of racks increased, suggesting pigs experienced less competition with more racks.

Contributions:

This article is important because it suggests increasing the number of straw racks provided decreases competition and allows more pigs to engage in exploratory behaviour. This advances knowledge because it suggests as the accessibility of an enrichment material increases exploration increases and competition decreases. This article is also important because its results support the notion that the quantity/accessibility of a material, not just its suitability, plays an important role in its effectiveness as an enrichment material. I included this article in my literature review because it discusses how accessibility to enrichment material influences exploratory behaviour in pigs.

Emily Hickle
30016985

Day, J. E. L., Burfoot, A., Docking, C. M., Whittaker, X., Spooler, H. A. M., & Edwards, S. A. (2002). The effects of prior experience of straw and the level of straw provision on the behaviour of growing pigs. *Applied Animal Behaviour Science*, 76(3), 189–202.

[https://doi.org/10.1016/S0168-1591\(02\)00017-5](https://doi.org/10.1016/S0168-1591(02)00017-5)

Summary:

In barren housing environments, natural behaviours of pigs are hindered leading to adverse behaviours. Straw is believed to improve pig welfare because it allows expression of exploratory behaviours. The objective of this study was to determine if prior experience of straw affects the subsequent behaviour of growing pigs and if the provisioning of differing levels of straw affects the quality and quantity of straw-directed behaviour.

Growing/finishing pigs with or without prior experience of straw during farrowing and weaning were exposed to one of four levels of straw provision (none, minimal, substantial, or deep) to produce eight treatments. Each treatment consisted of 10 pigs and was replicated four times. Three focal pigs per treatment were observed over ten weeks using time sampling from 24-hour videotapes and direct ad libitum sampling.

Pigs with prior experience of straw bit pen-mates more than pigs with no prior experience when straw was not provided. Tail-biting was higher in pigs with no prior experience for the first three weeks of the experiment possibly reflecting a predisposition to tail-bite. These results suggest a pig's early life environment may affect responses to stressors later in life.

As straw provision increased rooting and ploughing behaviours increased and aggression, belly nosing, tail biting, ear chewing, and licking, biting, and nosing pen-mates decreased. This further confirms the benefits of straw and is in accordance with other studies that suggest straw enhances welfare by providing an outlet for exploratory behaviours.

It was observed that pig interaction with straw increased with increasing straw provision, suggesting the quantity of straw-directed behaviour was proportional to straw amount, but the diversity of straw directed behaviour was not greatly affected. Pigs without prior experience of straw initially expressed certain straw-directed behaviours more, suggesting the value of straw as enrichment may be influenced by prior experience.

Contribution:

This article advances knowledge because it suggests that moving pigs from previously strawed housing to housing without straw increases the occurrence of adverse pen-mate directed behaviours. This is important because it suggests that experience with straw early in life impacts the expression of behaviours later in life. I included this article in my literature review because it discusses how a pig's prior experience with or without straw early in life affects the behaviours it expresses later in life.

Emily Hickle
30016985

Pedersen, L. J., Herskin, M. S., Forkman, B., Halekoh, U., Kristensen, K. M., & Jensen, M. B. (2014). How much is enough? The amount of straw necessary to satisfy pigs' need to perform exploratory behaviour. *Applied Animal Behaviour Science*, 160, 46–55.

<https://doi.org/10.1016/j.applanim.2014.08.008>

Summary:

Incidence of abnormal behaviour in pigs, such as oral manipulation of pen-mates indicates restriction of a behavioural need. It was previously found that oral manipulation of pen-mates decreases as the amount of straw provided increases up to 1kg per pig and day. The objectives of this study were to determine the amount of straw required to minimize oral manipulation of pen-mates and assess the amount of straw needed to assure permanent access.

The experiment was run in three batches each consisting of 48 pens of 18 pigs. The first sought to narrow the range for the optimal amount of straw. The second and third batches tested eight equidistant treatments of straw within this range. Three focal pigs per pen were selected and their behaviour recorded continuously for 12h when the pigs weighed approximately 40 and 80 kg. The concept of bioequivalence was used to determine the minimum amount of straw above which would not induce a meaningful reduction in oral manipulation of pen-mates. They predefined two amounts of straw to be biologically equal when the difference in oral manipulation was less than 20% of that between 10 and 500g straw per pig and day. In batches two and three, each pen was ranked as having (0) <1dL, (1) >1dL and <1L, (2) >1L and <10L, or (3) >10L of unsoiled straw after 24h. A score of 2 was considered to indicate permanent access.

The first batch demonstrated the optimal amount of straw was below 500g per pig and day. A linear decline in the amount of oral manipulation of pen-mates was observed in batches two and three and based on bioequivalence 387g straw per pig and day was the optimal amount to minimize oral manipulation. Based on this, the amount they predetermined as permanent access was likely too small.

Contributions:

This article is important and advances knowledge because to the authors knowledge this study is the first to provide a scientifically based estimate of the amount of straw necessary to meet growing pigs behavioural need to explore. They determine this amount to be 387g straw per pig and day using bioequivalence. I included this article because it determines the amount of straw necessary to fulfill the exploratory needs of pigs. It also discusses how abnormal behaviours may be used as an indicator of unfulfilled exploratory behaviour and it uses bioequivalence, a technique I had not heard of previously.

Emily Hickle
30016985

Day, J. E. L., Van de Weerd, H. A., & Edwards, S. A. (2008). The effect of varying lengths of straw bedding on the behaviour of growing pigs. *Applied Animal Behaviour Science*, 109(2), 249–260. <https://doi.org/10.1016/j.applanim.2007.02.006>

Summary:

Chewing, rooting, and nosing are natural tendencies for pigs owing to exploratory and foraging motivation. Barren pens inhibit these behaviours and can result in undesirable behaviours. Full-length straw has been demonstrated to halt the development of elevated levels of tail-biting. The objective of this study was to determine if chopped straw of varying lengths would produce similar benefits to pig welfare as full-length straw. They hypothesized all lengths of straw would reduce adverse behaviours directed towards pen-mates, and with increasing straw length, the quality and quantity of straw-directed behaviours would also increase.

Four treatments consisting of no straw, full-length straw, half chopped straw, and fully chopped straw were tested. There were six replicates made up of ten pigs for each treatment. Two females and two males from each pen were randomly selected as focal animals and were observed for six minutes in weeks one, four, seven, and ten using ad libitum sampling, allowing for the frequency of straw and pen-mate directed behavioural elements to be measured.

The proportional frequencies of pen-mate directed behaviours nosing, aggression, and tail-biting were significantly reduced with the provision of straw. Furthermore, groups provided straw versus no straw were more active overall, and when active demonstrated more diverse behaviours. However, tail-biting was higher in the fully chopped treatment than the full-length and half chopped treatments. This indicates chopped straw does not prevent tail-biting like full-length straw. They suggest this could be due to chopped straw stimulating exploratory behaviours that cannot be fulfilled because of the straws physical form, causing frustration. However, this hypothesis requires further study. The proportional frequency of the behaviour lick was increased in the chopped straw treatment while the behaviour pick was reduced. They suggest this is due to the pigs being unable to pick up chopped straw, so they reverted to licking.

Contribution:

This study is important because it further supports the idea that straw as an enrichment material stimulates diverse active behaviour in pigs and reduces pen-mate directed behaviours like tail-biting. This article advances knowledge because it offers new findings that suggest straw with reduced length still stimulates exploration but is less effective at fulfilling this behavioural need in pigs because of its physical form. I included this article in my literature review because it discusses the influence of straw length on the quality of exploratory behaviour and prevalence of pen-mate directed behaviour, especially tail-biting.