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1 **Evaluating measures of exploratory behaviour in sows around farrowing and during lactation**
2 **- A pilot study**

3

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12

13 **Abstract**

14 There are very few studies on the need to perform exploratory behaviour of sows around farrowing
15 and during lactation, except for during the nest-building period. Exploratory behaviour in pigs may
16 reflect appetitive foraging motivated by hunger, or appetitive behaviour related to other
17 motivations, such as nest building. However, exploration may also be motivated by curiosity,
18 stimulated by novelty or search for novelty. The aim of this study was to test novel methods of
19 evaluating exploratory motivation in sows around farrowing and during lactation. We used ten
20 second or third parity sows, housed in conventional crates from day 8 before expected farrowing
21 until weaning, on day 28 after farrowing. Motivation to perform exploratory behaviour was
22 evaluated by measuring the use of a manipulable and chewable object (a wooden device, MCO) and
23 responses during a novel object test (NO). In addition, we studied if exploratory motivation is
24 related to the energy status of the sow, measured as sow weight change during lactation, piglet
25 weight gain, and leptin level in saliva. The exploratory motivation of sows appeared to change

26 during the period of study. Although all sows used the MCO, the use was very low throughout the
27 study (below 3 g per day on average), and almost non-existent during the first weeks after
28 farrowing. The latency to touch the object in the NO test was correlated between test days before
29 and after farrowing, while the sow showed more interest in the object before than after farrowing.
30 MCO use during the last week of lactation was higher in sows with a lower weight after weaning,
31 suggesting a link between explorative motivation and energy status in the sow. These results
32 indicate a need for further studies on how to best meet the possible exploratory need of sows during
33 their time in the farrowing room.

34

35 **Keywords**

36 Exploration, sow, lactation, energy status, manipulable object, novel object

37

38 **1 Introduction**

39 In intensive pig production slatted floors and liquid manure management makes it difficult to use
40 straw, or similar manipulable and destructible material for pigs, which provides a suitable outlet for
41 exploratory motivation (Bracke et al., 2006; Studnitz et al., 2007). Lack of manipulable material has
42 been discussed mostly in relation to growing pigs (Vanheukelom et al., 2012), likely due to the fact
43 that this is closely related to the problem of tail biting in this age group (EFSA, 2014; D'Eath et al.,
44 2014). However, access to appropriate manipulative material might also be crucial for the welfare
45 of gestating sows (Munsterhjelm et al, 2015), and is certainly important for pre-farrowing sows
46 during the nest building phase (for a review, see Yun and Valros, 2015).

47

48 Very few studies have looked at behaviour directed towards manipulable materials in sows during
49 late gestation and lactation, except in relation to nest-building. Bulens et al. (2014) found that crated
50 sows used only a very small amount of straw from a straw dispenser, both before and after

51 farrowing. These authors did, however, speculate that this might have been due to the sows having
52 little experience extracting straw from the dispenser. In a small pilot study we found that lactating
53 sows in crates manipulated a piece of fresh wood hanging above the feeding trough very little
54 (Telkänranta et al, *unpublished*). This was surprising, as similar wood pieces were manipulated
55 frequently by fattening pigs, and also reduced the level of tail biting in these pigs (Telkänranta et
56 al., 2014). However, the low use of the wood pieces in sows may have been due to suboptimal
57 location of the wood. Farrowing crates greatly limit sow movements, and thus also restrict the
58 possibilities of sows to fulfil several needs, such as for nest-building (as reviewed by Yun and
59 Valros, 2015). However, as crates are widely used, there is a need for further investigation of how
60 to provide materials for sows in farrowing crates and the explorative motivation in these sows in
61 general.

62
63 In pregnant sows it has been suggested that exploratory behaviour is mainly appetitive foraging, due
64 to restrictive feeding, resulting in sows experiencing high levels of hunger during this period
65 (EFSA, 2014). During lactation sows are usually fed ad libitum, and should not experience hunger
66 as such. However, due to milk production there are high metabolic demands on sows during this
67 period (Valros et al., 2003a). Even ad libitum feeding may not be enough to meet the nutritional
68 needs of sows during this period of high metabolic demand. In addition to hunger, exploration may
69 also be motivated by curiosity, representing a search for or interest in novelty, but the distinction
70 between appetitive foraging behaviour and curiosity-motivated exploratory behaviour may be
71 difficult to make (Studnitz et al., 2007). Several experimental studies show that pigs tend to be more
72 interested in investigating novel objects than familiar ones (Wood-Gush and Vestergaard, 1991;
73 Moustgaard et al., 2002; Kornum et al., 2007). Further, just before farrowing, sows are highly
74 motivated to nest build, which increases their use of manipulable materials, such as straw (Haskell

75 and Hutson, 1996). The exploratory activity of sows, and the motivation behind it, can thus be
76 expected to change during the physiologically diverse period the sows spend in the farrowing unit.

77

78 If exploratory motivation in sows is mainly related to feeding motivation (EFSA, 2014), it could be
79 expected that exploratory behaviour is linked to measures related to the energy status of the sow.

80 Sows generally lose weight during lactation due to the high demand for milk production (Valros et
81 al., 2003a). The level of weight loss is individual, and associated to the energy status of the sow pre-
82 farrowing (Prunier et al., 2001). Weight loss during lactation, weight at weaning, and milk
83 production, indirectly measured as piglet growth, thus give crude indications of the energy status of
84 the lactating sows. The hormone leptin, which is mainly produced in the adipose tissue, is involved
85 in regulating feeding motivation and is positively related to energy status of the individual (Gautron
86 and Elmquist, 2011). In sows, leptin level has been shown to be related to level of backfat and to
87 long-term feeding level (Prunier et al., 2001; Summer et al., 2009; Cools et al., 2013). Leptin level
88 is thus a potential indicator of long-term energy status.

89

90 The aim of this study was to test novel methods of evaluating the exploratory motivation of sows
91 during the period from late gestation to weaning. We evaluated the use of a wooden manipulable
92 and chewable device and the interest in novel objects, focusing on changes throughout the study
93 period. In addition, we studied measures related to the energy status of the sows: weight, weight
94 loss, piglet growth and leptin level, to make preliminary observations on a possible positive
95 association between exploratory motivation and low energy status of the sow.

96

97 **2 Material and methods**

98 The study complied with a protocol approved by the Danish Animal Experiments Inspectorate
99 (2013–15–2934–00822).

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2.1 Animals, housing and management

The study was performed at Aarhus University, AU-Foulum, Denmark, in the period May to July 2015, and included 10 clinically healthy 2 or 3 parity (Danish crossbred Landrace x Yorkshire) sows. All sows originated from the same herd and had been crated during farrowing in earlier parities. Approximately 4 weeks before expected farrowing the sows were brought to the research centre and were group housed until approximately 2 weeks before expected farrowing. Here they were moved to individual farrowing pens, and further to farrowing crates on day 8 before expected farrowing. On day 23 after farrowing, five randomly selected sows were moved to farrowing pens, as part of another study. The piglets were weaned at 25-29 days (average 26.8) of age.

All the sows were housed in one climate-controlled farrowing room in identical farrowing crates of 4.8m² in size including 2.1m² of slatted floor and a 0.6m² creep area (Figure 1). The covered creep areas were placed either to the right or left in the front corner of the pen. The farrowing pens were 6.6m² including a 2.7m² slatted floor area and a creep area of 0.87m². The creep areas in both crates and pens had a 2.5cm thick rubber mat as surface and a heat source, which was turned off 10 days after farrowing.

Sows were fed three times a day at 0800 h, 1600 h, and 2100 h. During gestation the sows were fed 3.4 kg/day with a standard diet for gestating sows of (12 % CP, 102 FE/kg = 7.9 MJ PPE/kg). During lactation the feed was a standard diet for lactating sows (14.1% CP, 8.2 MJ PPE/kg), and the sows received 2.5 kg at the day of expected farrowing. Every day after farrowing the ration was evaluated and was increased or decreased according to the requirements of the individual sow, which was assessed based on a visual assessment of left over feed. Individual feed intake was not measured. Furthermore, sows received 200 g of chopped wheat straw daily, placed on the floor near the head of the sow, but not in contact with the creep area. From day 10 after birth the piglets were provided with a solid feed ad

126 libitum. From day 115 of gestation of the first expected farrowing until the last sow had farrowed in
127 the room, the light was turned on during 24 hours a day; this was necessary to record the farrowing
128 times on video for another study. After the last farrowing in a room, the light was on from 0600-
129 1800h. A small window brought in natural daylight.

130
131 Eight sows gave birth to more than 14 piglets and the first morning after farrowing, the litter size of
132 these was standardised to 14 piglets by taking randomly selected piglets from the litter to be
133 fostered by non-experimental sows. Two sows gave birth to only 13 live-born piglets, and no piglets
134 were added to these litters. The piglets were earmarked and within five days after farrowing, the
135 males were castrated.

136

137 ***2.2 Data collection and sampling procedures***

138 Piglet weights were recorded from the actual days after farrowing while all other measures are in
139 relation to the expected farrowing date, giving a variation of -1 to + 3 days in relation to actual
140 farrowing date. The sampling and testing schedule is illustrated in Figure 2.

141

142 To evaluate the motivation to explore a manipulable and chewable object (MCO), a piece of fresh
143 willow, approximately 30 cm long and 6 cm in diameter was attached to the front part of the crate
144 structure before the sows were moved into the crates. The wood hung from a chain, about 2-3 cm
145 above the floor, and was easily accessible by the sow (Figure 1). On day 23 the wood was moved
146 with the sow to the pen for those sows being moved on that day. The wood was weighed before
147 attaching it, on day 2 pre partum, and days 1, 23 and 27 postpartum. The average daily wood
148 reduction was calculated (grams/day) as an estimate of MCO use for each sow and period, based on
149 the exact amount of days for each sow: Period 1, P1 (days 8 to 2 prepartum), P2 (day 2 prepartum to
150 day 1 postpartum), P3 (days 1 to 23 postpartum) and P4 (days 23 to 27 postpartum).

151

152 To test for interest in novelty, sows were presented with novel objects (NO) in their farrowing crate.
153 Testing was performed twice during the experimental period: day 3 pre farrowing and day 19 post
154 farrowing. The test was performed between 1000h and 1200h. The objects used included white
155 plastic flower pots, plastic cups of different colours and a plastic spaghetti spoon. The sows got a
156 different object on each test day, and the objects were given in random order. The sow was first
157 urged to stand up, and her attention towards the object direction was assured. The object, which was
158 hanging from a rope, about 40 cm above the floor, above the feed trough was then presented and
159 made available to the sow. During 10 min following presentation of NO the following variables
160 were recorded from video: latency to touch the object in seconds (NO latency); total duration of
161 interaction with the object (NO duration); and number of interaction bouts with the object (NO
162 frequency). NO interaction was defined as the sow touching the object with her snout, and the
163 object moving as a result of this. If the sow did not touch the object at all, the NO latency was
164 recorded as 600 s.

165

166 Piglets were weighed individually on days 1, 4, 7, 14 and 21 postpartum. Sows were weighed when
167 moved to the farrowing unit (on day 8 before expected farrowing), and on the day of weaning.

168

169 Saliva samples for leptin analyses were obtained using Salivette® tubes by allowing the sow to
170 chew on the swab for approximately 1 minute, or until the swab was clearly wet. The sows were
171 used to the sampling procedure, as they had been trained and then sampled, as part of another study,
172 already during 3 previous days. Saliva samples were collected on day 3 before expected farrowing
173 and day 15 after farrowing, at 0530h (before morning feeding) and at 1730h (after afternoon
174 feeding). The samples were taken long enough after feeding to avoid feed residuals in the saliva.
175 Salivette tubes were centrifuged for 10 min at 1000 x g and saliva samples were stored at – 80 °C

176 until analysis. For statistical analyses morning and afternoon samples were pooled and average
177 daily leptin level is reported.

178

179 ***2.3 Leptin analyses***

180 Before analysis, saliva samples were centrifuged for 5 min at 10000 x g to remove particulates and
181 the clear supernatant was diluted 3-fold with DPBS, pH 7.0-7.2 (Dulbecco's phosphate buffered
182 saline, Biochrom GmbH, Berlin, Germany). Leptin concentrations were measured as duplicates
183 using a commercial ELISA kit for porcine samples (Cloud-Clone Corp., Wuhan, China) according
184 to the manufacturers' instructions. The kit is a sandwich enzyme immunoassay for the quantitative
185 measurement of leptin in porcine serum, plasma, tissue homogenates and other biological fluids and
186 it has been used successfully to measure leptin concentrations in pig serum and plasma (Walsh et
187 al., 2013; Yang et al., 2013, Duan et al., 2014). The intra- and inter-assay coefficients of variations
188 were 9.2% and 11.8%, respectively. Serial saliva dilutions were assayed by ELISA to assess
189 parallelism. Parallelism proved acceptable between samples diluted 3-fold to 10-fold ($R^2 = 0.9963$).
190 The detection range for diluted samples was 0.06 – 4.00 ng/ml. The detection limit for the diluted
191 samples was 0.03 ng/ml, determined as the concentration of the leptin measured at two standard
192 deviations from the zero standard along the standard curve.

193

194 ***2.4 Statistical methods***

195 All statistical analyses were performed with IBM SPSS 21.

196

197 Average daily MCO use, as well as NO latency, NO duration and NO frequency could not be
198 assumed normally distributed, and the difference between periods for MCO use (P1, P2, P3, P4)
199 and test days for the NO variables (day - 3 and day 19) was tested with Friedman's two-way

200 analyses of variance by ranks, followed by Bonferroni-corrected pairwise comparisons when
201 appropriate.

202

203 To test if the MCO and NO variables were consistent within sow over time, correlations between
204 periods P1, P2 and P4 (9 of 10 sows did not used MCO in P3) for MCO use and test days for the
205 NO variables were tested using Spearman rank correlations. A possible association between MCO
206 use and NO was tested using Spearman rank correlations for MCO use P1 (P2 was excluded in all
207 further correlations, as we were most interested in exploratory behaviour not directly related to nest
208 building) against NO day -3, and MCO P4 use against NO day 19, respectively. Finally, measures
209 of exploratory motivation (MCO and NO) were correlated to measures related to sow energy status
210 using Spearman rank correlations for two time periods separately: MCO use in P1 as well as NO
211 variables day -3 were correlated with leptin day -3, and sow weight on day 8 before farrowing. Use
212 of the MCO in P4 as well as NO variables day 19 were correlated with leptin day 15, sow weight at
213 weaning, sow weight change, and piglet ADG during all periods. Only correlations which are
214 significant ($p < 0.05$) or tend to be significant ($p < 0.1$) are reported in the text.

215

216 The effect of moving sows to pens at day 23 on MCO use was tested with Mann-Whitney U tests,
217 but as no effect was found this is not reported.

218

219 **3 Results**

220

221 ***3.1 Measures of exploratory motivation: Use of the manipulable and chewable object and*** 222 ***behaviour during the novel object test***

223 The use of the MCO differed between the different periods ($\text{Chi}^2(3) = 12.6, p = 0.006$), with very
224 little use of the MCO overall, especially during the first 3 weeks after farrowing (P3). Pairwise

225 comparisons are reported in Table 1. The use of MCO did not correlate within sow between the
226 different periods ($p > 0.1$ for all).

227

228 The sows had a longer NO latency on day 19 postpartum than on day 3 prepartum ($Z = 2.7$, $p =$
229 0.008) and a shorter NO duration ($Z = -2.4$, $p = 0.02$) on day 19 postpartum than day 3 prepartum
230 (Table 2). There was no difference in NO frequency between the two test days. The latency to touch
231 the object showed consistency within sow as it was correlated between test days 3 prepartum and 19
232 postpartum ($r = 0.75$, $p = 0.02$). No other inter-day correlations between the test parameters were
233 found ($p > 0.1$ for all). On day 3 prepartum all sows interacted with the NO at least once, while on
234 day 19 postpartum one sow never touched the NO.

235 The use of the MCO did not correlate with any of the NO variables (latency duration, frequency) at
236 either time point ($p > 0.05$ for all).

237

238 ***3.2 Piglet performance and sow weight***

239 Descriptive data for piglet ADG, number of live and stillborn piglets, mortality of liveborn piglets
240 until day 21, as well as sow weight and weight change, and leptin level are presented in Table 3.

241

242 ***3.4 Correlations between measures of exploratory motivation and measures related to sow energy*** 243 ***status.***

244 Frequency of NO interactions on day 19 correlated negatively with leptin level on day 15 ($r = -0.70$,
245 $p = 0.04$).

246

247 MCO use during P4 correlated negatively with sow body weight at weaning ($r = -0.80$, $p = 0.005$).

248

249 All other correlations between the MCO and NO variables on one hand, and the measures of sow
250 energy status on the other were non-significant ($p > 0.05$ for all).

251

252 **4 Discussion**

253 This pilot study supports previous observations of a minor motivation of sows in manipulating a
254 piece of fresh wood during the period in the farrowing room. The novel object test indicated a
255 higher interest in novelty before farrowing than during lactation. Further, we found some
256 preliminary interactions between measures of exploratory motivation in sows and measures related
257 to energy status of the sow, which warrant further research.

258

259 All sows used the manipulable and chewable object at some stage of the experimental period, but
260 the use was minor. The use did, contrary to our expectations, not increase significantly before
261 farrowing, i.e. during the nest building period. Even though a piece of wood does not provide a
262 possibility to actually nest build, and increase in redirected nest-building type manipulation, such as
263 bar biting, has been reported in pre-farrowing sows (Yun et al., 2015). During the first three weeks
264 after farrowing use of the MCO was close to zero, only one sow used it at all. This might be due to
265 a low feeding motivation and motivation for feeding-related exploratory behaviour (appetitive
266 foraging) due to a change to ad libitum feeding at this point. During week 4 after farrowing the
267 sows started using the MCO again, which may indicate an increased motivation to forage, due to an
268 increasing metabolic load towards the end of lactation (Valros et al., 2003a), which cannot be fully
269 compensated by feed intake. This theory is supported by the fact that MCO use during the last week
270 before weaning correlated negatively with sow weight at weaning, with lighter sows using the MCO
271 more. Weight change from before farrowing until weaning was not correlated to weaning weight
272 and did not correlate with MCO use. However, weight loss was correlated with pre-farrow weight,

273 indicating that weight loss mainly reflects the energy status of the sows at the beginning of
274 lactation, a correlation which has been reported previously (Prunier et al., 2001).

275

276 An alternative explanation for the low MCO use during the first weeks of lactation is that other
277 motivations are of higher priority at this stage, such as those related to piglet care and nursing. Also
278 in rats, it has been shown that dams decrease their exploratory behaviour during the beginning of
279 lactation, while returning to prepartum levels again when the pups are 20 days of age (Genaro &
280 Schmidek, 2002). Another motivation that might override the need for exploration in early lactation
281 is resting motivation, causing a decreased general activity level. Sows spend most time lying
282 laterally and show a low activity level during the beginning of lactation, with an increase after the
283 second week post partum (Valros et al., 2003b, Lambertz et al., 2015). Regrettably, we cannot fully
284 exclude that the piglets were using the MCO during the study period, as it was within their reach.
285 However, it is very unlikely that piglets of this age would be able to chew pieces off a wood of this
286 size (\emptyset 6 cm).

287

288 The low usage level of MCO in crated lactating sows is in concordance with our previous
289 experience (Telkänranta, *unpublished*) where we found sows not to use wood significantly during
290 lactation. Also Bulens et al. (2014) found sows in farrowing crates to use only small amounts of
291 straw when testing a straw dispenser (3.2 g per day), with no difference between the period before
292 and after farrowing. A wooden piece and straw that is not easily distracted from a dispenser may not
293 represent available manipulative materials for sows. Thus, it is possible that alternative materials
294 and alternative ways to provide materials may represent better out-lets for exploratory motivation in
295 lactating sows. There is a need to investigate this topic further, by, for example, comparing
296 motivation to access a wood piece and straw in a rack to straw provided on the floor. Furthermore,
297 instead of merely comparing time spent and instead of simple preference tests, substitutability and

298 quantitative preference may be established using double demand functions (Jensen and Pedersen,
299 2008). However, providing sows with appropriate manipulable material in crates is practically
300 challenging. The crate offers a very restricted space for providing material in a suitable location,
301 and any bedding-type material, such as straw, easily ends up out of reach of the sow. Bedding-type
302 material also easily falls through slatted flooring, commonly used in farrowing pens. The use of
303 straw and similar materials is further limited on-farm, as they may cause problems in slurry-based
304 manure handling systems.

305

306 The sows in this study were more interested in exploring a novel object before than after farrowing,
307 with all sows interacting with the object 3 days prior to farrowing. This supports the findings from
308 the use of the MCO, with sows being less interested in the wood during the three first weeks of
309 lactation than before farrowing. Also day 19 after farrowing, however, most sows interacted with
310 the object during the 10 minute test period. Latency to touch the object on day 3 before and day 19
311 after farrowing correlated positively, indicating that there is some individual stability in the
312 measure. However, the frequency of NO interaction did not differ between periods. Moreover,
313 MCO and NO variables did not correlate, which cautions interpretation of these two in relation to
314 exploratory motivation. Possibly, MCO primarily reflects appetitive foraging, while NO primarily
315 reflects exploratory response to novelty.

316

317 The fact that a higher frequency of NO interaction was associated to a lower level of leptin on day
318 19 after farrowing could suggest a link between interest in novelty and the energy status of the
319 sow, i.e. that sows with a high energy status have a lower general curiosity. However, the results are
320 not highly convincing since leptin only correlated to NO frequency, not to NO latency and NO
321 duration. Leptin did not correlate to the MCO use either, thus we cannot conclude on a link between
322 leptin and exploratory motivation based on the present results. A high level of leptin signals satiety

323 at high energy status (Berthoud, 2005) and has been shown to affect feed intake negatively also in
324 pigs (Barb et al., 1998). Leptin has also been reported to be higher in sows with a higher backfat
325 level during gestation (Cools et al., 2013) and lactation (De Rensis et al., 2005), which suggest
326 further studies to clarify this link could be warranted.

327

328 As far as we know, there are no studies comparing levels of leptin in saliva and plasma in pigs, but
329 in humans a good correlation has been reported (Gröschl et al., 2001, Randeva et al., 2003),
330 showing a higher level of leptin in plasma than in saliva samples. Level of leptin in the saliva
331 samples of the current study was also lower (overall average 1.7 ng/ml) than has been reported for
332 plasma samples: between 2.2 and 5.9 ng/ml in a corresponding period around farrowing (Govoni et
333 al., 2007; Cools et al., 2013; Saleri et al., 2015).

334

335 **5 Conclusions**

336 The exploratory motivation of sows appears to change during the period of study, being higher
337 before than after farrowing, and especially low during the first weeks after lactation. There is a need
338 for further studies on how to best provide an outlet for exploratory motivation of sows during their
339 time in the farrowing room, and to better understand the reason for the apparently low exploratory
340 motivation after farrowing. These preliminary results suggest that explorative motivation in sows
341 might be linked to the energy status of the sow, but this still needs to be confirmed.

342

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350

351 **7 References**

352 Barb CR, Yan X, Azain MJ, Kraeling RR, Rampacek GB, Ramsay TG. Recombinant porcine leptin
353 reduces feed intake and stimulates growth hormone secretion in swine. *Domest Anim Endocrinol*
354 1998;15:77– 86.

355

356 Berthoud HR. A new role for leptin as a direct satiety signal from the stomach. *Am J Physiol Regul*
357 *Integr Comp Physiol* 2005;288:796–7.

358

359 Bracke MBM, Zonderland JJ, Lensens P, Schouten WGP, Vermeer HM, Spoolder HAM et al.
360 Formalised review on environmental enrichment for pigs in relation to political decision making.
361 *Appl Anim Behav Sci* 2006;98:165–82.

362

363 Bulens A, Renders L, Beirendonck SV, Thielen JV, Driessen B. An exploratory study on the effects
364 of a straw dispenser in farrowing crates. *J Vet Behav* 2014;9:83-9.

365

366 Cools A, Maes D, Decaluwé R, Buyse J, van Kempen TY, Janssens GP. Peripartum changes in
367 orexigenic and anorexigenic hormones in relation to back fat thickness and feeding strategy of sows
368 *Domest Anim Endocrinol* 2013;45:22–7.

369

370 D'Eath RB, Arnott G, Turner SP, Jensen T, Lahrmann HP, Busch ME, Niemi JK, Lawrence AB,
371 Sandøe P. Injurious tail biting in pigs: how can it be controlled in existing systems without tail
372 docking? *Anim* 2014;8:1479–97.

373

374 De Rensis F, Gherpelli M, Superchi P, Kirkwood RN. Relationships between backfat depth and
375 plasma leptin during lactation and sow reproductive performance after weaning. *Anim Reprod Sci*
376 2005;90:95–100.

377

378 Duan Y, Li F, Li L, Fan J, Sun X, Yin Y. n-6:n-3 PUFA ratio is involved in regulating lipid
379 metabolism and inflammation in pigs. *Br J Nutr* 2014;111:445–51.

380

381 European Food Safety Authority. Scientific opinion concerning a multifactorial approach on the use
382 of animal and non-animal-based measures to assess the welfare of pigs. *EFSA J* 2014;12:3702 [101
383 pp.].

384

385 Gautron L, Elmquist JK. Sixteen years and counting: an update on leptin in energy balance. *J Clin*
386 *Invest* 2011;121:2087–93.

387

388 Genaro G, Schmidek. The influence of handling and isolation postweaning on open field,
389 exploratory and maternal behavior of female rats. *Physiol & Behav* 2002;75:681-688.

390

391 Govoni N, Parmeggiani A, Galeati G, Penazzi P, De Iasio R, Pagotto U et al. Acyl ghrelin and
392 metabolic hormones in pregnant and lactating sows. *Reprod Domest Anim* 2007;42:39–43.

393

394 Gröschl M, Rauh M, Wagner R, Neuhuber W, Metzler M, Tamgüney G et al. Identification of
395 leptin in human saliva. *J Clin Endocrinol & Metabolism* 2001;86:5234–9.

396

397 Haskell MJ, Hutson GD. The pre-farrowing behaviour of sows with straw and space for
398 locomotion. *Appl Anim Behav Sci* 1996b;49:375-87.
399

400 Jensen MB, Pedersen LJ. Using motivation tests to assess ethological needs and preferences. *Appl*
401 *Anim Behav Sci* 2008;113:340-356.
402

403 Kornum BR, Thygesen KS, Nielsen TR, Knudsen GM, Lind NM. The effect of the inter-phase
404 delay interval in the spontaneous object recognition test for pigs. *Behav Brain Res* 2007;181:210–
405 17.
406

407 Lambertz C, Petig M, Elkmann A, Gauly M. Confinement of sows for different periods during
408 lactation: effects on behaviour and lesions of sows and performance of piglets. *Anim* 2015;9: 1373–
409 1378.
410

411 Moustgaard A, Lind NM, Hemmingsen R, Hansen AK. Spontaneous object recognition in the
412 Göttingen minipig. *Neural Plasticity* 2002;9:255-59.
413

414 Munsterhjelm C, Heinonen M, Valros A. Application of the Welfare Quality® animal welfare
415 assessment system in Finnish pig production, part II. Associations between animal-based and
416 environmental measures of welfare. *Anim Welf* 2015;24:161-72.
417

418 Prunier A, Meija Guadarrama CA, Mourot J, Quesnel H. Influence of feed intake during pregnancy
419 and lactation on fat body reserve mobilisation, plasma leptin and reproductive function of
420 primiparous lactating sows. *Reprod Nutr Dev* 2001;41:333–47.
421

422 Randeve HS, Karteris E, Lewandowski KC, Sailesh S, O'Hare P, Hillhouse EW. Circadian
423 rhythmicity of salivary leptin in healthy subjects. *Mol Genet and Metabolism* 2003;78:229–35.
424

425 Saleri R, Sabbioni A, Cavalli V, Superchi P. Monitoring blood plasma leptin and lactogenic
426 hormones in pregnant sows. *Anim* 2015;9:629–34.
427

428 Studnitz M, Jensen MB, Pedersen LJ. Why do pigs root and in what will they root? A review on the
429 exploratory behaviour of pigs in relation to environmental enrichment. *Appl Anim Behav Sci*
430 2007;107:183–97.
431

432 Summer A, Saleri R, Malacarne M, Bussolati S, Beretti V, Sabbioni A et al. Leptin in sow:
433 Influence on the resumption of cycle activity after weaning and on the piglet gain. *Livest Sci*
434 2009;124:107–11.
435

436 Telkänranta H, Bracke MBM, Valros A. Fresh wood reduces tail and ear biting and increases
437 exploratory behaviour in finishing pigs. *Appl Anim Behav Sci* 2014;161:50-9.
438

439 Valros A, Rundgren M, Špinká M, Saloniemi H, Rydhmer L, Hultén F et al. Metabolic state of the
440 sow, nursing behaviour and milk production. *Livest Prod Sci* 2003a;79:155-67.
441

442 Valros A, Rundgren M, Špinká M, Saloniemi H, Algers B Sow activity level, frequency of lying
443 down and anti-crushing behaviour – within sow-repeatability and interactions with nursing
444 behaviour and piglet performance. *Appl Anim Behav Sci* 2003b;83:29-40.
445

446 Vanheukelom V, Driessen B, Geers R. The effects of environmental enrichment on the behaviour of
447 suckling piglets and lactating sows: A review. *Livest Sci* 2012;143:116–31.
448

449 Walsh AM, Sweeney T, Bahar B, O’Doherty JV. Multi-functional roles of chitosan as a potential
450 protective agent against obesity. *PLOS ONE* 2013;8:1.
451

452 Wood-Gush DGM, Vestergaard K. The seeking of novelty and its relation to play. *Anim Behav*
453 1991;42:599–606.
454

455 Yang H, Li F, Xiong X, Kong X, Zhang B, Yuan X et al. Soy isoflavones modulate adipokines and
456 myokines to regulate lipid metabolism in adipose tissue, skeletal muscle and liver of male
457 Huanjiang mini-pigs. *Mol and Cell Endocrinol* 365;2013:44–51.
458

459 Yun J, Valros A. Benefits of prepartum nest-building behaviour on parturition and lactation in sows
460 (review). *Asian-Australasian J Anim Sci* 2015;28:1519-24.
461

462 Yun J, Swan K, Oliviero C, Peltoniemi O, Valros A. Effects of prepartum housing environment on
463 abnormal behaviour, the farrowing process, and interactions with circulating oxytocin in sows. *Appl*
464 *Anim Behav Sci* 2015;162:20-25.
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Tables

Table 1. Average daily use of a manipulable and chewable wood object (MCO) by sows during four different periods from the week before farrowing until weaning (n = 10).

	Median and (interquartile range) ³	N sows ²	Min	Max
MCO P1, g/day ¹	2.8 (1.0) ^a	10	0.5	3.4
MCO P2, g/day	2.9 (5.3) ^a	9	0	111
MCO P3, g/day	0 (0) ^b	1	0	11.5
MCO P4, g/day	2.7 (14.6) ^{ab}	7	0	51.4

¹ P1: day 8 to day 2 prepartum; P2: day 2 prepartum to day 1 postpartum; P3: day 1 to day 23 postpartum; and P4: day 23 to 27 postpartum.

² Number of sows for which MCO was more than 0 during the different periods

³ The lack of a common letter in the superscript indicates a difference between periods

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Table 2. Results from a novel object test (NO) performed with sows before and after farrowing (n = 10).

	Day 3 prepartum		Day 19 postpartum	
	Median and (interquartile range)	Min-Max	Median and (interquartil e range)	Min-Max
NO latency, s ¹	1 (3) ^a	0-23	19 (83) ^b	3-600
NO duration, s ²	44 (124) ^a	2-549	8 (41) ^b	0-71
NO frequency ³	3 (3)	2-6	3 (3)	0-5

¹ Latency to touch the object

² Total duration of interaction with the object

³ Number of interaction bouts with the object

⁴ The lack of a common letter in the superscript indicates a difference between days

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514 Table 3. Descriptive statistics for litter characteristics, piglet average daily weight gain (ADG), sow
 515 weight and weight change and leptin level (n = 10)

	Median and (interquartile range)	Min	Max
Liveborn piglets	17 (9)	13	22
Stillborn piglets	2.5 (2)	0	6
Mortality of liveborn until day 21	1.0 (3)	0	3
	Mean and (standard deviation)		
Piglet ADG day 1-4, g	153 (26)	120	200
Piglet ADG day 4-7, g	199 (48)	110	280
Piglet ADG day 7-14, g	235 (59)	140	330
Piglet ADG day 14-21, g	245 (48)	180	330
Piglet ADG day 1-21, g	222 (40)	170	280
Sow weight day 8 prefarrowing, kg	279 (22)	252	323
Sow weight at weaning (day 28), kg	241 (14)	223	271
Sow weight change, kg	-38 (17)	-77	-19

Leptin day 3 prefarrowing, ng/mL	1.46 (0.70)	0.27	2.21
Leptin day 15 postfarrowing, ng/mL	2.04 (1.14)	0.49	3.81

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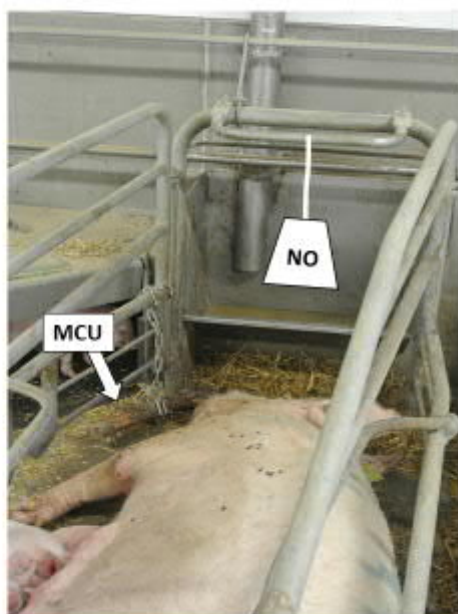
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520 **Figures**

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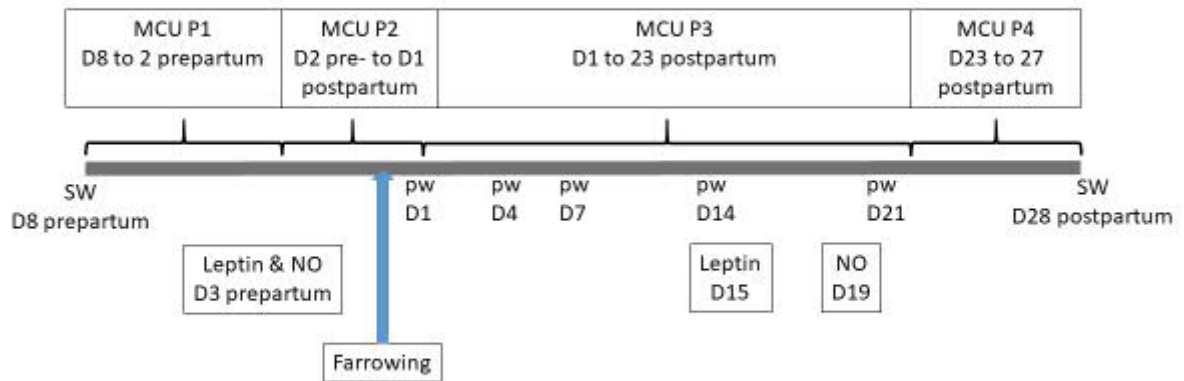
Figure 1



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523 Figure 1. Illustration of the position of the manipulable and chewable object (MCO) and the novel
524 object (NO) during the novel object test.

Figure 2



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526 Figure 2. Diagrammatic presentation of the sampling schedule. The use of manipulable and
527 chewable object (MCO) was evaluated during 4 periods (P): P1 (days 8 to 2 prepartum), P2 (day 2
528 prepartum to day 1 postpartum), P3 (days 1 to 23 postpartum) and P4 (days 23 to 27 postpartum).

529 SW: sow weighing, pw: piglet weighing, NO: novel object test.

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