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RESEARCH ARTICLE

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Effect of stocking density and use of environmental enrichment materials on the welfare and the performance of pigs in the growth and finishing phases

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Abstract

Aim of study: To evaluate the effects of stocking density and the use of environmental enrichment (EE) objects on the welfare and the performance of pigs in the growing and finishing phases.

Area of study: The southern region of Brazil.

Material and methods: A total of 240 pigs, 120 immunocastrated males and 120 females, with an initial weight of 22.38 ± 2.38 kg and mean age of 65 days, were submitted to two stocking densities conditions (0.85 and 1.28 m^2pig) with and without EE for 117 days. The experimental design was a 2×2×2 factorial (two categories, two densities, and two EE conditions), with six replicates. Performance variables and behavior were evaluated.

Main Results: For stocking density, there was a significant difference in the finishing phase from 148 to 161 days of age for the final weight (FW), average daily weight gain (ADWG), and feed conversion rate (FCR). For the EE factor, there was no difference in any of the phases or in the overall period. In the overall period, the higher availability of space improved the results of FW (140.56 kg *vs* 136.63 kg), ADWG (1.005 kg *vs* 0.974 kg), and FCR (2.05 *vs* 2.10). There was no effect of EE, stocking densities, or their interaction on the frequency of different behaviors of the pigs in the growth and finishing phases.

Research highlights: There was no effect of interactions between enriched environments, stocking densities, and sex for animal performance and behavioral frequencies; however, differences between the factors were observed separately. The higher availability of space improved the results of FW, ADWG, and FCR.

Additional key words: animal welfare; space allowance; toys.

Abbreviations used: ADFI (average daily feed intake); ADWG (average daily weight gain); EE (environmental enrichment); FCR (feed conversion rate); FW (final weight).

Authors' contributions: Conceived and designed the experiments: EDC, AM and CAS. Performed the experiments: EDC and AM. Analyzed the data: SMS and LF. Interpretation of data: LF and CRP. Technical support: JGND, JVSD, CCRS. Wrote the paper: EDC, LF, CAS.

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Introduction

Barren environments with restricted space availability can prevent pigs from exhibiting behavioral repertoires and present a challenge for the expression of performance characteristics and the maintenance of wellbeing levels (Fraser & Broom, 1997; Averós *et al.*, 2010; Ludtke *et al.*, 2014). For this reason, the European Union has established minimum requirements for the use of environmental enrichment (EE) by means of Directive 2008/120, requiring the supply of "manipulable materials" for pigs at all stages of life. This legislation states that pigs must have permanent access to a sufficient quantity of material to enable adequate exploration and handling (EU, 2008).

The term EE implies improvements, whether they are physical, social, or alimentary, applied to change in a favorable way the environment of confinement (Newberry, 1995) and this has gradually been applied in industrial swine (Ickes *et al*., 2000; Van de Weerd *et al.*, 2003; Campos *et al.*, 2010). Research suggests that the use of EE objects in the pens reduces the occurrence of negative social interactions (Guy *et al.*, 2002; Rodarte *et al.*, 2004), favors psychological and physiological well-being, stimulates behaviors typical of the species, and makes the captive environment more complex (Campos *et al.*, 2010), which can also contribute to productive performance.

Furthermore, the high animal stock density within the pens might negatively impact the performance of pigs (Brumm, 1996; Vermeer *et al.*, 2014) and increase negative interactions (Scollo *et al.*, 2014). Research suggests that both the performance and welfare of animals depend on the complexity of the environment and not only on isolated factors (Scollo *et al.*, 2014). Thus, to promote animal welfare, different strategies can be adopted simultaneously and, in this sense, both EE and stocking densities can be implemented or modified with relative ease, including in the commercial sphere.

Given the above, the aim of conducting this study was to evaluate the effects of stocking densities and the use of objects for EE on the welfare, husbandry, and economic performance of pigs in the growing and finishing phases.

Material and methods

All procedures adopted in the conduct of this research were reviewed and approved by the Animal Use Ethics Committee of the State University of Londrina under protocol no. 14093.2018.83.

A total of 240 animals were used, of which 120 were immunocastratred males and 120 females, with an average weight of 22.38 ± 2.38 kg and age of 65 days. The animals were maintained until 182 days of age, with an average final weight of 138 ± 2.38 kg. The animals were identified with earrings at the time of the first weighing (65 days old). Prior to the start of the experiment, the animals were kept under the same conditions of rearing and experienced the same transport conditions until the evaluation was implemented. Males received a commercial immunocastration vaccine (Vivax®) at 95 and 163 days of age. A nutritional program was adopted, consisting of six phases (Table 1) based on the requirements according to their weight and age range, with feed and water being provided ad libitum throughout the experimental period.

The animals, five per group of the same sex, were housed in masonry pens with natural ventilation, equipped with a bowl-type drinking fountain and linear feeders with access to all animals simultaneously. The 48 pens used had a solid floor and an initial area of 1.28 m^2/animal. Of these, 24 pens were reduced to a final area of 0.85 m^2/animal. The reduction in the size of the pens was accomplished with wooden partitions positioned longitudinally in the pens, without interfering with the access to the feeder and water fountain. The average temperature during the experiment was 26.73 ± 3.22˚C.

Twenty-four pens were equipped with EE objects. PVC structures with four pieces of flexible hose, sisal ropes fixed at the ends of the pens, pieces of wood on the floor of the pen, and suspended metal chains were individually used as EE objects, and were rotated every 29 days in the order quoted previously (Fig. 1). Although more than one artifact was used for EE, the focus of this work was not to evaluate the attractiveness of the objects, but rather the effects of the availability of EE. The exchange of objects was adopted in order to extend the interest of the animals in the object and also due to operationally feasible duration for commercial conditions.

The experimental design was in blocks in a 2×2×2 factorial scheme, with two animal categories (inmunocastrated males and females), two levels of stocking densities (0.85 m^2 per animal and 1.28 m^2 per animal), and EE (with or without). The blocking criterion was the initial weight of the animals which were divided into light, medium, and heavy. Behavioral assessments; tail, ear, and body lesion scores; as well as the performance variables: final weight (FW), average daily weight gain (ADWG), feed conversion rate (FCR), and average daily feed intake (ADFI) were evaluated.

Performance analyses

For the performance analyses, the animals were weighed on the first day of the experiment and after each feed exchange on days 20, 41, 61, 83, 96, and 117 days of lodging (phases 1 to 5).

Behavior analysis

Behavioral evaluations were performed using images captured with video cameras installed at the top of the pen. For this, four pens were evaluated, one for each treatment, using only the males. The cameras were installed

Table 1. Percentage composition and calculated nutrient composition of feed.

Ingredients (%)	G 1 (65-82 days)	G2 (83-100 days)	G 3 (101-118 days)	F 1 (119-136 days)	F 2 (137 -154 days)	F 3 (155 - 172 days)
Corn	68.296	72.581	74.776	68.116	70.319	71.586
Soybean meal 46%	17.800	15.000	14.000	13.900	13.400	12.300
Flour of poultry viscera overlay	8.000	7.000	6.000	-	-	-
Soybean oil	3.380	2.980	2.800	3.540	2.890	2.750
Calcitic Limestone 38%	0.803	0.786	0.774	0.726	0.727	0.725
Barley	-	-	-	7.000	7.000	7.000
Meat and bone meal	-	-	-	5.000	4.000	4.000
L-lisine HCL liquid 50%	0.623	0.609	0.612	0.621	0.582	0.575
Methionine liquid 88%	0.176	0.145	0.132	0.163	0.151	0.139
L-threonine 98.5%	0.152	0.139	0.136	0.175	0.178	0.172
Salt	0.530	0.540	0.550	0.539	0.553	0.553
Premix vit/min growing 1	0.240	-	-	-	-	-
Premix vit/min growing 2	-	0.220	-	-	-	-
Premix vit/min growing 3	-	-	0.220	-	-	-
Premix vit/min finising 1	-	-	-	0.220	-	-
Premix vit/min finising 2	-	-	-	-	0.200	-
Premix vit/min finising 3	-	-	-	-	-	0.200
Total	100.000	100.000	100.000	100.000	100.000	100.000
Nutrients						
Crude protein (%)	19.09	17.49	16.59	15.73	15.14	14.72
Metabolizable energy (kcal/kg)	3484	3464	3454	3468	3433	3427
Ethereal extract	7.15	6.69	6.43	6.94	6.22	6.10
Crude fiber (%)	1.87	1.81	1.78	1.88	1.89	1.87
Calcium (%)	0.92	0.85	0.79	0.85	0.76	0.76
Total phosphorus (%)	0.53	0.49	0.46	0.49	0.45	0.44
Tryptophan (%)	0.23	0.21	0.20	0.19	0.18	0.18
Total lysine (%)	1.31	1.20	1.13	1.07	1.01	0.98
Methionine (%)	0.42	0.38	0.36	0.35	0.34	0.32

G1=growing 1; G2=growing 2; G3 =growing 3; F1=finishing 1; F2=finishing 2; F3=finishing 3 .

Figure 1. Environmental enrichment objects offered to pigs in the growing and finishing phases. Wooden blocks on the floor (A), hoses coupled to a PVC structure (B), sisal rope fixed to the pen walls (C), and suspended metal chains (D).

only in treatment pens of males with independent adjustments, targeting the objects and focusing on the entire pen. The images were recorded for 24 hours per day of evaluation and subsequently visually analyzed. The pigs were numbered to facilitate their subsequent identification in videos.

Behavioral observations started when the pigs were 95 days old and ended at 164 days. The images of four days of lodging throughout the experimental period were observed. At the time of observations, the animals were 95, 123, 140 and 164 days old, respectively. Subsequently, the recordings were evaluated every 10 minutes in the period between 00:00 and 22:30, resulting in a total of 677 scans per pen of observations in a pen, or 2708 behavioral observations per pen during the experimental period. The observations were used to compose a histogram, characterizing the respective proportions of time dedicated to each behavior present in the ethogram (Table 2), developed by adapting the methodology proposed by Van de Weerd *et al.* (2003) and Docking *et al.* (2008).

Statistical analyses

The performance data were submitted to an analysis of variance and, after verification of the interaction between the factors, the means of the factors were isolated and compared using the F-Test. In addition to the mean total period, analyses of variance were performed for the performance characteristics in each ration, being represented by phases 1 to 5, respectively. The behavioral data were submitted to normality analysis by the Shapiro-Wilks test and after finding the non-normality, the averages were analyzed by the Kruskal-Wallis. For this, "dplyr" and "rstatix" packages, applying Bonferroni for p-adjustment. All statistical analyses were performed using software R version 3.5.0.

Table 2. Ethogram for the evaluation of pig behavior according to the presence of environmental enrichment objects. Adapted from Van de Weerd *et al.* (2003) and Docking *et al.* (2008).

Behavior	Description
Interacting with the object	Manipulation of the point-source object: smelling, biting, pushing, chewing, craving.
Agonistic	Behavior regarding fights, involving exhibitions, escapes, fights, bites and scratches between the pigs
Inactive	Standing, sitting, lying down, sleeping.
Active	All active behaviors, excluding interactions with the object. *i.e.*, drinking, eating, social interactions, exploring the pen.

Results

There was no interaction effect between the EE factors, densities, and sex for animal performance (Table 3). However, differences between the factors were observed in isolation. Considering the total period of the evaluation, the females presented worse values of FW, ADWG, and FCR than the males, and the higher availability of space improved the results for FW, ADGW, and FCR. The observations of lesions and pathologies were not noteworthy.

The EE alone did not promote differences in the performance of the animals in any of the evaluated phases. In phase 5 of the experiment, differences were observed for FW, FCR, and ADWG and in phase 6, for PF for the space availability factor. The sex factor, however, presented a difference in almost all phases for FW, FCR, and ADWG, and only in phase 6 did the females present better values for the FCR and ADWG. Regarding salivary cortisol concentrations, there was no effect of the factors on the concentration in the two evaluated periods (Table 4).

The results of the behavioral frequency analysis are shown in Table 4. There was no effect of EE, stocking densities, or interaction (p>0.05) on the behavioral frequency of pigs in the growth and finishing phases. The occurrence of active behaviors was not influenced by the presence of EE objects or by stocking densities levels. In general, pigs spent more of their time inactive than doing other activities.

Discussion

Studies indicate that the genetic potential for protein deposition in intact males is better than that in castrated males and females (Porolnik *et al.*, 2012). Reducing the available space for pigs commonly results in reduced feed efficiency and weight gain and increases the incidence of undesirable behaviors (Averós *et al.*, 2010; Kim *et al.*, 2017). However, Jang *et al.* (2017) emphasized that reduced spaces negatively impacts the performance of finishing pigs, but does not affect animals in the growth phase. However, the authors worked with densities of 0.96, 0.80, and 0.69 m²/pig, which are values higher than those adopted in our study, reinforcing the idea that the higher the stocking density, the greater the competition for resources and, consequently, the higher the level of stress experienced by the animals, thus promoting performance worsening.

Other reports in the literature confirm the results obtained in our study. White *et al.* (2008) found reductions of 17% in ADFI and 10.7% in ADWG by restricting the available space from 0.93 to 0.66 m²/pig. In the study by Kerr *et al.* (2005), point stocking density effects were observed on the performance variables of pigs. On the fifth and eighth week of the stay, the pigs kept at a low stocking density (2 m²/pig) presented higher weight gain than those housed under high stocking density conditions (1 m²/pig) (8.23 kg *vs* 7.42 kg and 8.83 kg *vs* 7.69 kg, respectively).

However, the results of the present study differ from those observed by Patton *et al.* (2008). When evaluating different densities (0.70 m²/pig *vs* 1.13 m²/pig), the authors did not observe differences in performance in the growth and finishing phases. The present study also shows divergent results from Gentry *et al.* (2002), who worked with lower densities (0.90 m²/pig *vs* 9.45 m²/pig) and did not observe improvements in pig performance.

There is a concordance of the negative effect of increasing the stocking density of the animals in the stages of growth and finishing on the variables of zootechnical performance. However, there are still few data regarding the effects of possible alterations to the materials used for EE to compensate for the reduced performance due to higher housing densities. Beattie *et al.* (2000) observed better values of food consumption, feed conversion, growth rate, and final weight for growing pigs kept in bins enriched with dispensers containing peat and straw under a very generous condition of pen area (3.5 m²/pig).

Studying different types of EE, Van de Weerd *et al.* (2006) found higher weight gain results in environments enriched with a shaving bed but no advantages were found when they used point-source EE similar to that adopted in our research In addition, Casal-Plana *et al.* (2017) observed higher body weights for pigs kept in enriched environments (hemp ropes, sawdust, rubber balls) and/or supplemented with herbal compounds (*Valeriana officinalis* and *Passiflora incarnata*) between 22 and 24 weeks of age.

In the studied condition, the absence of significant effects of EE to minimize the negative effects of the worst stocking density condition are in agreement with the findings of Vermeer *et al.* (2017), who did not find any effects of EE on the production variables of pigs, but found that the higher availability of space (1 m²/pig *vs* 0.8 m²/pig) resulted in a higher ADWG, and that males had a higher growth rate than females.

The influence of EE on the performance of pigs is more noticeable when straw is used as EE material or when the overlapping bedding condition is adopted (Van de Weerd & Day, 2009; Averós *et al.*, 2010). Although these materials have a high attractiveness value (Studnitz *et al.*, 2007), their use, especially in slatted floor pens, can make it difficult to handle waste and clean the pen (EFSA, 2005), in addition to compromising the operational and financial viability of the system (Nannoni *et al.*, 2017). Even if they are considered strategically important, enrichment objects should not be seen as a final solution to pig welfare problems, and if they are not in line with sanitary and nutritional variables, their benefits might not be observed.

Table 3. Performance of pigs in the growth phase and total period, housed at different stocking densities, with or without the use of environmental enrichment, and by sex.

Variables	Stocking density (m²/pig)		*p*-value	Environmental enrichment		*p*-value	Category		*p*-value
	0.85	1.28		With	Without		Female	Male	
Phase 1									
FW (kg)	38.13 ± 3.30	38.68 ± 2.99	0.547	38.54 ± 3.19	38.27 ± 3.16	0.768	37.95 ± 3.63	38.86 ± 2.56	0.323
FCR	1.53 ± 0.10	1.48 ± 0.10	0.173	1.51 ± 0.10	1.50 ± 1.10	0.717	1.55 ± 0.11	1.46 ± 0.06	0.001
ADFI (kg)	1.19 ± 0.63	1.19 ± 0.73	0.774	1.19 ± 0.71	1.18 ± 0.65	0.698	1.18 ± 0.79	1.19 ± 0.53	0.711
ADWG (kg)	0.78 ± 0.06	0.80 ± 0.07	0.392	0.79 ± 0.08	0.79 ± 0.61	0.969	0.77 ± 0.08	0.81 ± 0.04	0.02
Phase 2									
FW (kg)	56.39 ± 4.37	57.22 ± 3.49	0.469	56.79 ± 3.97	56.82 ± 3.99	0.966	55.73 ± 4.32	57.88 ± 3.11	0.05
FCR	1.87 ± 0.13	1.85 ± 0.08	0.418	1.88 ± 0.10	1.84 ± 0.11	0.192	1.92 ± 0.11	1.80 ± 0.08	<0.001
ADFI (kg)	1.62 ± 0.05	1.63 ± 0.05	0.597	1.63 ± 0.04	1.62 ± 0.06	0.378	1.62 ± 0.05	1.63 ± 0.04	0.337
ADWG (kg)	0.87 ± 0.08	0.88 ± 0.05	0.5	0.86 ± 0.06	0.88 ± 0.07	0.466	0.84 ± 0.06	0.90 ± 0.06	<0.001
Phase 3									
FW (kg)	78.79 ± 4.85	79.79 ± 3.40	0.438	79.10 ± 3.97	79.43 ± 4.44	0.784	77.45 ± 4.48	81.08 ± 2.93	<0.001
FCR	1.85 ± 0.11	1.85 ± 0.08	0.848	1.86 ± 0.06	1.84 ± 0.12	0.652	1.91 ± 0.09	1.79 ± 0.05	<0.001
ADFI (kg)	2.06 ± 0.05	2.07 ± 0.04	0.646	2.06 ± 0.05	2.07 ± 0.04	0.635	2.06 ± 0.04	2.06 ± 0.04	0.947
ADWG (kg)	1.11 ± 0.06	1.12 ± 0.04	0.748	1.10 ± 0.04	1.12 ± 0.06	0.379	1.08 ± 0.04	1.15 ± 0.03	<0.001
Phase 4									
FW (kg)	102.34 ± 6.41	104.26 ± 4.26	0.229	103.36 ± 4.87	103.24 ± 6.12	0.94	100.2 ± 5.69	106.92 ± 2.98	<0.001
FCR	2.32 ± 0.22	2.25 ± 0.12	0.173	2.27 ± 0.13	2.30 ± 0.21	0.511	2.39 ± 0.16	2.18 ± 0.13	<0.001
ADFI (kg)	2.46 ± 0.12	2.50 ± 0.72	0.187	2,.49 ± 0.07	2.46 ± 0.12	0.398	2.45 ± 0.12	2.50 ± 0.06	0.141
ADWG (kg)	1.07 ± 0.12	1.11 ± 0.07	0.152	1.10 ± 0.07	1.08 ± 0.13	0.511	1.03 ± 0.10	1.15 ± 0.07	<0.001
Phase 5									
FW (kg)	118.88 ± 7.23	122.73 ± 4.66	0.03	120.93 ± 5.61	120.68 ± 7.08	0.893	116.99 ± 6.20	124.62 ± 3.60	<0.001
FCR	2.10 ± 0.18	1.91 ± 0.23	0.002	2.01 ± 0.22	2.00 ± 0.24	0.864	2.08 ± 0.22	1.92 ± 0.20	0.01
ADFI (kg)	2.65 ± 0.12	2.67 ± 0.06	0.326	2.69 ± 0.05	2.64 ± 0.12	0.13	2.66 ± 0.11	2.66 ± 0.07	0.885
ADWG (kg)	1.27 ± 0.14	1.42 ± 0.17	0.002	1.35 ± 0.16	1.34 ± 0.18	0.849	1.29 ± 0.16	1.40 ± 0.17	0.02
Phase 6									
FW (kg)	136.63 ± 6.23	140.56 ± 4.71	0.01	138.81 ± 5.44	138.38 ± 6.27	0.803	135.61 ± 6.23	141.59 ± 3.40	<0.001
FCR	2.98 ± 0.34	3.02 ± 0.38	0.672	2.99 ± 0.34	3.01 ± 0.39	0.87	2.84 ± 0.23	3.16 ± 0.39	0.001
ADFI (kg)	2.49 ± 0.07	2.53 ± 0.07	0.1	2.52 ± 0.07	2.50 ± 0.08	0.477	2.50 ± 0.08	2.52 ± 0.07	0.404
ADWG (kg)	0.847 ± 0.08	0.85 ± 0.11	0.89	0.85 ± 0.09	0.84 ± 0.09	0.766	0.88 ± 0.07	0.81 ± 0.10	<0.001
Overall period									
IW (kg)	22.49 ± 2.33	22.36 ±2.48	0.885	22.38 ± 2.45	22.37 ± 2.36	0.979	22.28 ± 2.73	22.48 ± 2.03	0.525
FW (kg)	136.63 ± 6.23	140.56 ± 4.71	0.001	138.81 ± 5.44	138.38 ± 6.27	0.803	135.61 ± 6.23	141.59 ± 3.40	<0.001
FCR	2.10 ± 0.07	2.05 ± 0.05	<0.001	2.08 ± 0.06	2.07 ± 0.07	0.436	2.12 ± 0.05	2.03 ± 0.05	<0.001
ADFI (kg)	2.05 ± 0.55	2.06 ± 0.03	0.203	2.06 ± 0.44	2.05 ± 0.05	0.313	2.05 ± 0.05	2.07 ± 0.03	0.113
ADWG (kg)	0.974 ± 0.04	1.005 ± 0.03	0.002	0.990 ± 0.04	0.989 ± 0.04	0.962	0.963 ± 0.04	1.016 ± 0.02	<0.001
ADFI (kg)	2.05 ± 0.55	2.06 ± 0.03	0.203	2.06 ± 0.44	2.05 ± 0.05	0.313	2.05 ± 0.05	2.07 ± 0.03	0.113
ADWG (kg)	0.974 ± 0.04	1.005 ± 0.03	0.002	0.990 ± 0.04	0.989 ± 0.04	0.962	0.963 ± 0.04	1.016 ± 0.02	<0.001

Initial weight (IW), final weight (FW), feed conversion rate (FCR), average daily weight gain (ADWG), and average daily feed intake (ADFI).

According to Vermeer *et al.* (2014), the use of EE requires pens with more space for pigs during the growing and finishing phases than those used under intensive commercial conditions. In parallel, Zwicker *et al.* (2013) argue that, especially in the finishing phase, feeding management ad libitum results in a lower motivation of the animals to express exploratory behaviors, and this might be why no advantages were observed for the EE.

Apart from these results, it should be considered that productivity is not always an indicator of animal welfare, although some variables, such as decreasing the mortality rates and the percentage of animals affected by injuries and pathologies, might indirectly indicate improvements in terms of animal welfare. However, when considering farms with a high performance are considered, this equation is more complex (Dias *et al.*, 2014). This is supported by the results of the present study, which showed that the occurrence of lesions and pathologies was not noteworthy.

The results of the analysis of behavioral frequencies in our study are in agreement with those found by Bracke (2007) and Telkänranta *et al.* (2014). According to Machado *et al.* (2017), the success of an enrichment object should not be measured solely by its ability to attract the attention of pigs, but also by its ability to reduce undesirable behavior.

When living free in the wild, pigs tend to spend most of the day exploring the environment in an attempt to find food (Putten, 2000). However, under confinement conditions, where water and food are provided *ad libitum*, the motivation to express exploratory behavior is reduced (Zwicker *et al.*, 2013).

Beattie & O'Connell (2002) and Stern & Andersen (2003) reported that in situations of food restriction, there was an increase in exploratory behavior, reinforcing the idea that the active behaviors of pigs are largely motivated by the demand for food. In the present study, regardless of stocking density, there was no impediment to access to feeders and drinkers, which might have contributed to the increase in the incidence of inactive behaviors.

The results we obtained are in agreement with Machado *et al.* (2017) and Foppa *et al.* (2018), who observed that the animals spent on average 65% and 55.38%, respectively, of their time inactive. Although the numbers presented in these studies are smaller than the values obtained in our study, in both studies, the observation period was diurnal, at which time the animals were more active. In our study, the behavioral assessment also comprised the nocturnal period, resulting in an increased incidence of inactive behaviors. The results regarding the behavioral repertoire of pigs in the presence of EE objects and when housed at different densities still remain controversial in the literature; however, caution is needed when comparing the data. Considering that pig behaviors are influenced by factors such as genetics, nutrition, ambience, size of the group, characteristics inherent to the individual, and the physical structure of the accommodation (Deen, 2010), one must be attentive to the different factors when interpreting the responses.

Although they did not find differences in the occurrence of most active behaviors, Cornale *et al.* (2015) reported the influence of stocking density, the presence of EE, and their interaction on the manifestation of feeding behaviors and inactive behaviors. However, in their study, the different densities were regulated by the number of animals present in the pen and not by their size. Therefore, access to the feeder was compromised by the higher number of animals present in the pen, which probably generated differences in the feeding of these animals. In our study, the stocking density was regulated by the physical space in the pen, without, however, compromising the simultaneous access of all the pigs to the feeders. This contributed to reduce the stress generated by the space constraint.

In contrast, Casal-Plana *et al.* (2017) observed an increase in the exploratory behavior by offering different objects for EE (hemp ropes, sawdust, rubber balls, and a herbal compound), suggesting that pigs that have access to EE are more stimulated than those in barren pens. In addition, the stimulation of the animals might be linked to the characteristics of the objects, since pigs have a preference for chewable, destructible, rooted, and deformable materials (Van de Weerd *et al.*, 2003; Bolhuis *et al.*, 2005).

Table 4. Effects of stocking density (SD) and environmental enrichment (EE) on the behavioral frequency (%) of pigs in the growth and finishing phases.

Behavior	SD 0.85 (m²/pig)		SD 1.28 (m²/pig)		*p*-value		
	EE+	EE-	EE+	EE-	EE	SD	SD × EE
Inactive	83.22 ± 7.42	81.93 ± 7.42	82.33± 8.24	83.98 ± 7.19	0.802	0.923	0.053
Active	14.81 ± 6.41	16.88 ± 6.33	15.97 ± 7.38	14.95 ± 6.20	0.714	0.981	0.116
Agonistic	1.00 ± 1.05	1.19 ± 1.47	0.82 ± 1.04	1.07 ± 1.43	0.645	0.454	0.878
Interaction with object	0.97 ± 1.25	-	0.88 ± 1.55	-	-	0.196	0.196

EE+ = pens with environmental enrichment; EE- = pens without environmental enrichment

When analyzing the behavioral repertoire throughout the days, the results demonstrate that the availability of EE in the pens can be effective at mitigating the occurrence of fights in the first days of batch mixing. Our results corroborate those obtained by Schaefer *et al.* (1990) and Ishiwata *et al.* (2002), who reported the reduction of aggressive occurrences in pigs with access to objects of EE. Similarly, Cornale *et al.* (2015) observed a significant reduction in the occurrence of aggressive behaviors in enriched pens (1.30% *vs* 0.61%), a reduction in the incidence of caudophagia, and an increase in the occurrence of positive social interactions.

Pigs are hierarchical animals and when exposed to unfamiliar animals, tend to become aggressive in order to determine dominance roles. This period can extend for a few days (Meese & Ewbank, 1973). Considering that the regrouping of pigs in intensive production systems is a common practice, EE could be considered a way to reduce the stress experienced, especially in the first days of housing.

Another factor that may have contributed significantly to the presented behavioral repertoire is the temperature. During the experimental period, average temperatures (26.73 ± 3.22˚C) were significantly above the comfort zone for growing and finishing pigs (18 to 23 ˚C). High ambient temperatures are a challenge for pig production and when exposed to high ambient temperatures, pigs present changes in behavioral pattern.

According to Broom & Fraser (2010), pigs, in confinement conditions, spend most of their time resting and sleeping. However, in an attempt to curb metabolic heat production, pigs, under heat stress, tend to spend even more idle time. This fact was also observed by Huynh *et al.* (2005). In a study evaluating the behavioral repertoire of pigs under thermal stress (21 °C *vs* 31 °C), Kiefer *et al.* (2009) observed that animals kept under heat stress remained lying longer.

In summary, the higher availability of space improved the results for final weight, daily weight gain, and feed conversion. EE did not influence the behavior of growing finish-pigs.

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