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Behaviour and performance of pigs finished on deep bedding with wood shavings or rice husks in summer

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Abstract

Concern that excessive temperatures arising from substrate fermentation could have a deleterious effect on voluntary feed intake and weight gain, especially during the hottest times of the year, might be a barrier to the widespread adoption of deep-bedding systems for pig production in Brazil. The aim of this study was to compare the behaviour and performance of pigs reared on deep bedding with two different substrates, wood shavings and rice husks, or in barren, part-slatted, concrete-floored pens (n = 4 pens per treatment), from 60 days of age through to slaughter, during the summer months in Santa Catarina, southwest Brazil. Floor and pigs' skin temperatures were 2.2 and 3.9% higher, respectively, in the pens with bedding than with concrete flooring; these differences resulted in modest, non-significant effects on performance and meat quality. Certain elements of the behaviour of pigs reared with bedding, such as increased play activity and substrate manipulation and less peer-directed behaviours, indicated improved welfare compared to pigs reared in concrete-floored pens. Performance and meat quality were similar in bedded pens with either wood shavings or rice husks. In both bedding substrates, the animals spent more time lying or standing on the beds than on the concrete platforms, where the feed and the water troughs were located, despite the higher temperature in the substrate compared to the concrete platform; suggesting that such temperature differences were not relevant for the thermal comfort of the animals. These results indicate that both substrates, abundant and readily available in the region, are suitable bedding materials for pigs.

Keywords: *animal welfare, enrichment, housing, performance, redirected behaviours, rooting material*

Introduction

Brazil has the fourth largest commercial swine herd in the World, behind China, the EU and the United States (FAO 2008). The state of Santa Catarina is responsible for 27% of national pig meat production (IBGE 2007) and an even larger proportion of the exports. Most pigs in this region are finished in conventional housing with concrete or concrete-slatted flooring. Together with the social conflict caused by the lack of space and mixing of groups, the absence of material for manipulation is one important source of poor welfare in conventional pig-rearing systems (Studnitz *et al* 2007). This is reflected in a high frequency of behaviours redirected to objects and pen parts and to other animals in the pens, and results in problems such as skin lesions (Turner *et al* 2006), cannibalism (van de Weerd *et al* 2005), physiological stress (Chaloupková *et al* 2007) and lower product quality (Beattie *et al* 2000).

Environmental enrichment has been suggested as an option for improving welfare in barren housing. Objects such as tyres, ropes and chains, frequently used in Brazilian farms as sources of enrichment, do not present the characteristics most valued by pigs which have been described by van de Weerd *et al* (2003); as a consequence, the animals lose interest in such objects after a relatively short period of time (Blackshaw *et al* 1997; van de Weerd *et al* 2005; Scott *et al* 2006a). The use of bedding, on the other hand, addresses a fundamental factor behind the behavioural problems observed in pigs housed in confinement, which is the difficulty in fulfilling the motivation associated with foraging behaviours (Newberry 1995; Bracke & Hopster 2006). Thus, pigs use substrates more frequently and for a longer duration than objects (Scott *et al* 2006a; van de Weerd *et al* 2006). The use of straw or other substrates, added over concrete flooring, has low acceptance as an enriching tool among Brazilian farmers, mainly because it is considered impractical and labour intensive. The use of deep bedding, widely accepted for poultry, remains low in Brazil for pig production. One of the reasons for this may be concerns that excessive temperature, as a result of fermentation of the substrate, could result in heat stress, reducing voluntary feed intake and weight gain of pigs (Nienaber *et al* 1996; Quiniou *et al* 2000; Rinaldo *et al* 2000). Nonetheless, a number of studies report better performance in pigs reared with rather than without bedding substrate (Lyons *et al* 1995; Guy *et al* 2002; Ramis *et al* 2005).

In general, it is believed that complex rooting materials have a larger capacity to stimulate extended explorative behaviour (Jensen & Pedersen 2007). In a review of the literature, Studnitz *et al* (2007) concluded that substrates that consist of small fragments, able to be chewed into smaller pieces and that may be eaten (such as peat, sand, sawdust and wood shavings), are amongst the most preferred by pigs. Building on this existing knowledge, substrates available in different regions need to be studied in order to help boost welfare-friendly pig production systems — a demand of consumers in industrialised countries (eg Honeyman 2005; EC 2007) and of a growing group of consumers in developing countries (eg Machado Filho 2000). In order to meet the expected improvement in the environmental, economic and ethical aspects of livestock production (Appleby 2005; Steinfeld *et al* 2006), the choice of substrate for bedding should be based on a range of criteria, including cost, regional availability, practical aspects related to use, resulting environmental and agronomic qualities after composting of the bedding, and the performance and welfare of the animals. This study focused on the final issue, with special interest on aspects of performance and behaviour that might be associated with the thermal comfort of the animals. Thus we sought to compare the behaviour and performance of pigs reared on deep bedding with two different substrates, wood shavings and rice husks, or on pens with part-slatted concrete flooring, from 60 days of age to slaughter, during the summer months — the most critical season for pigs in Santa Catarina, southwest Brazil.

Materials and methods

Animals, housing and treatments

This experiment was carried out at the experimental research station of EMBRAPA Swine and Poultry (Concórdia, Santa Catarina State, Brazil) between December 2002 and April 2003 (summer/autumn in the region). The climate in this area is defined as 'subtropical humid', with cold winters and hot summers and without a dry season.

A total of 216 pigs, crossbred from F1 females (Large White × Landrace) and MS (Duroc × Large White × Pietrain) males, were used. At the start of the study, the animals were 60 days old and had an average weight of 20.9 (± 0.8) kg. Prior to the study, they had been kept in the breeding-unit nursery of the experimental station, in conventional, indoor housing. Each naturally-ventilated nursery room contained five pens, in which six-to-eight male and female piglets of similar weight, weaned at 21 days of age, were housed in suspended metal cages (1.9 × 2.1 m; length × width) with a metallic slatted floor and fitted with one bowl drinker and one feeder, and no enrichment.

All piglets were ear-notched for identification and had their tails docked two days after birth while all males were castrated within seven days of birth.

Pigs were weighed and divided into three treatments with four replicates of 16 animals (eight males and eight females): deep bedding with one of the two following substrates; wood shavings (WS) or rice-husk bed (RH), or concrete, part-slatted flooring (CF). The animals were randomly distributed to treatments, adjusting for sex, weight and nursery pen of origin.

The experiment was run in three buildings located 10 m apart, each with four 30 m^2 pens separated by a 1 m high wall. CF pens had a 26 m^2 (5.2 × 5 m) area of compact concrete and a 4 m^2 slatted (0.8 × 0.8 m) area consisting of prefabricated concrete plates. No enrichment was provided in the CF pens. Each deep bedding pen had a 9 m^2 concrete platform (1.8 × 5 m) with a feeder located at its centre and a 21 m^2, 0.7 m deep bed. This allowed for 1.875 m^2 per animal in total and 1.3 m^2 bedding area, which is slightly higher than the recommended value of 1.2 m^2. The bedding used in the experiment had already been used in two previous groups. Substrate was not replenished during the study. Both types of pen had an automatic drinker located 3 m from the feeder and a feeder with capacity for 100 kg of ration, dispensable by automatic flux and endowed with two coupled water devices which allowed for the consumption of wet or dry feed. The feeder and drinker were located on the concrete platform. Water intake from feeders and drinkers was individually monitored through hydrometers.

Grower (60 to 123 days of age) and finisher (124 to 183 days of age) commercial, pelleted diets, containing no growth promoters or antibiotics and formulated to provide 3,300 kcal ME kg^{-1}, were offered *ad libitum*. The experiment lasted 123 days, ending in slaughter at 183 days. The crude protein content of the diet was 18.6, 16.9 and 15.2% and crude fibre content was 3.06, 2.9 and 2.75% for the beginning, middle and final phases, respectively.

The experimental protocol was approved by the Ethics Committee of the Federal University of Santa Catarina (CEUA/UFSC).

Behavioural variables

Behaviour was recorded through instantaneous scan sampling by direct visual observation (Altmann 1974) carried out by a single observer. Six focal animals were selected and identified in each pen; three males and three females. Animals that best approximated the average weight of the group, the 33% heaviest and the 33% lightest animals were used. The same animals were used in all behavioural observations from the beginning to the end of the study. Identification was made with a marker pen suitable to animal experimentation (non-toxic ink) applied on the loin of the focal animals.

Scans were made every 12 min from 0830 to 1130h and from 1400 to 1800h during four consecutive days at the beginning (ages 60–63 days), at the middle (ages 124–127 days) and at the end of the experiment (ages 179–183 days), in a total of 120 scans per period.

The pigs' positions — standing, lying and sitting — were recorded, as well as a series of mutually exclusive behaviours:

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eating, drinking, playing, fighting, oral-nasal interactions (nasal contact, ear and tail biting, belly-nosing were grouped), object manipulation, substrate manipulation, walking and idleness. The definition of the behaviours follows the description by Hötzel *et al* (2004) with the exception of substrate manipulation, which was defined as 'animal stirring the substrate with the snout or chewing a part of it'. The location of the animals in the pen area — the concrete platform or the bed — was recorded for the groups in deep bedding.

Performance and climatic variables

Performance variables recorded in this study were initial and final weight, water and feed intake, daily weight gain and feed/conversion ratio. After slaughter, carcase weight, bacon depth, loin depth; *m* longissimus dorsi) and percentage of dry meat in the carcass were assessed following the method of carcase classification by Sadia Concórdia SA (ABCS 1973) carried out at the cold-storage unit with a Hennessy electronic probe (Hennessy Grading Systems Ltd, New Zealand). Performance data were obtained from all the pigs in each group.

The surface temperature of the beds and the concrete floor, as well as the surface temperature of the skin of the focal animals, were monitored through an infrared thermometer with laser sight (Raytek Co, Germany) precise to ± 0.5ºC, at 0900 and 1500h, on behaviour-observation days. Readings were taken at the withers and middle ribs. For the measurement of surface temperature on the beds and concrete floor, the laser was directed at five fixed and pre-established points in the pen in the shape of an 'N'. Dry bulb temperature (air temperature), black globe (the effects of direct solar radiation on an exposed surface), relative air humidity and wind speed in the experimental buildings at the level of the animal were also monitored on the days of behavioural observations, with electronic sensors installed between treatment pens at a height of 0.6 m above the floor.

Statistical analysis

Behaviours were expressed as a frequency of occurrence per day, using pen as the experimental unit (n = 4). Effects of treatment (df = 2; except for distribution of the animals — on the bed or platform — when df = 1) and age of pigs (df = 2) on frequency of behaviours and climatic variables, and interactions between both (df = 4), were analysed using a mixed univariate model for repeated measures. Performance was analysed using a general linear model. Further comparisons between deep bedding vs concrete flooring and between wood shavings vs rice-husk bedding were made through orthogonal contrasts. Paired *t*-tests were used to investigate differences between means. All analyses were run with the SAS statistical package (SAS 1993).

Results

No interaction was found between the effects of treatment and age of the animals, for the time spent by pigs in the standing, sitting and lying positions. However, there was an effect of treatment ($P < 0.03$) for the standing position, which is explained by the fact that animals in WS bedding spent more time standing than animals in the RH bedding. There was also a significant effect of animals' age on the proportion of time spent standing and lying ($P < 0.001$) and sitting ($P < 0.02$). In all three treatments, the frequency of standing was higher when the animals were youngest and decreased thereafter; this was accompanied by a concomitant increase in the frequency of lying as the animals aged (Table 1).

Treatment by age interactions ($P < 0.04$; Table 2) were found for drinking behaviour, which was higher for WS than the other two treatments (WS: 3.6 [± 0.8]; RH: 4.1 [± 0.5]; CF: 3.0 [± 0.3]) only during the second phase of the study, and oral-nasal interactions, which were higher in CF (9.5 [± 1.5]) than WS and RH (5.5 [± 0.7] and 4.0 [± 0.2], respectively) only during the first phase of the study. There was also an interaction between the effects of treatment and age on oral-nasal contact behaviour ($P < 0.001$; Table 3), where the treatments differed in the first phase of the experiment only.

The observation period influenced the frequency of observation of all activities ($P < 0.01$; Tables 2 and 3). In the initial period, the frequencies of eating, playing and substrate manipulation behaviour were higher than the other two ages, whereas there were no differences in the middle and end of the study. Object manipulation, oral-nasal contact and idleness differed among all periods. Drinking, walking and fighting behaviours were less frequent at the final than at the two earlier periods of the experiment, which did not differ.

Treatment effects were found in the frequency of oral-nasal contact ($P < 0.005$), which was lower in RH bedding than in the other two treatments; of playing behaviour, which was lower in WS bedding than in the other two treatments ($P < 0.04$); object-manipulation behaviour, which was lower in RH bedding than in the other two treatments ($P < 0.05$) and idle behaviour, which was lowest in WS bedding and highest in CF pens ($P < 0.03$; Table 2).

When behaviour of pigs on deep bedding and concrete floor systems was contrasted, higher frequencies of playing behaviour and lower frequencies of oral-nasal contact and idleness were found in the deep-bedding system compared to concrete floor groups ($P < 0.05$).

When the behaviour of pigs on the two substrates used on the deep-bedding system was contrasted, higher frequencies of object manipulation, playing and oral-nasal behaviour were observed in the WS treatment ($P < 0.05$).

Regarding the distribution of the animals in the pen — on the bedded area or on the concrete platform — there were interactions between treatments and phases ($P < 0.001$), as well as an effect of treatment ($P < 0.05$) and of the age of the animals ($P < 0.01$). The pigs on the WS bedding spent more time on that bedding than those on RH bedding. In both treatments, the choice for the bedded area was highest in the third and lowest in the first period of the experiment; the animals reared on WS bedding spent more time on the bed in the first and second period of the experiment, compared to the pigs on the RH bedding (Table 4).

Performance and after-slaughter readings are presented in Table 5. None of the variables were significantly affected by treatment. Some differences or tendencies were found when

Table 1 Mean (± SE) relative frequencies of standing, sitting or lying in focal animals.

Treatment	Age	Standing (%)	Sitting (%)	Lying (%)
WS		34.2 ± 3.07^{a}	6.2 ± 0.45	59.7 ± 3.11
RH		27.3 ± 2.75^{b}	7.6 ± 0.71	65.1 ± 2.76
CF		30.3 ± 3.18^{ab}	6.1 ± 0.56	63.6 ± 2.83
	1	47.9 ± 1.98^{A}	5.2 ± 0.44^{B}	46.9 ± 1.86^{A}
	2	25.9 ± 1.30^{B}	7.7 ± 0.70^{A}	66.4 ± 1.49^{B}
	3	18.0 ± 1.28^{C}	6.8 ± 0.52^{AB}	75.2 ± 1.42^{C}

WF: deep bedding with wood shavings; RH: deep bedding with rice husks; CF: concrete flooring. 1: 60–63 days of age; 2: 124–127 days of age; 3: 179–183 days of age. Differences shown within columns, for treatment: ^{a,b,c}; for age: ^{A,B,C}: $P < 0.05$.

Table 2 Mean (± SE) relative frequencies of drinking, manipulating object, manipulating substrate, walking behaviours and idleness behaviour in focal animals.

Treatment	Age	Eating (%)	Drinking (%)	Manipulating object (%)	Manipulating substrate (%)	Walking (%)	Idle (%)
WS		12.7 ± 1.34	2.6 ± 0.36	2.1 ± 0.36^{a}	13.6 ± 1.26	3.5 ± 0.34^{b}	59.7 ± 3.27^{b}
RH		13.3 ± 1.64	2.8 ± 0.35	1.1 ± 0.14^{b}	10.9 ± 1.15	2.8 ± 0.28^{b}	65.0 ± 3.04^{ab}
CF		14.3 ± 1.59	3.1 ± 0.27	2.2 ± 0.32^{a}		4.5 ± 0.50^{a}	69.0 ± 2.73^{a}
	1	22.5 ± 0.84^{A}	3.4 ± 0.28^{A}	2.6 ± 0.35^{A}	17.2 ± 1.50^{A}	4.4 ± 0.37^{A}	47.3 ± 1.77^{C}
	2	8.7 ± 0.64^{B}	3.6 ± 0.32^{A}	1.8 ± 0.29^{B}	10.4 ± 1.12^{B}	4.6 ± 0.36^{A}	69.1 ± 1.75^{B}
	3	9.0 ± 0.77^{B}	1.6 ± 0.20^{B}	1.0 ± 0.15^{C}	9.2 ± 1.03^{B}	1.9 ± 0.19^{A}	77.3 ± 1.47^{A}

Differences shown within columns, for treatment: ^{a,b,c}; for age: ^{A,B,C}: $P < 0.05$.

Table 3 Mean (± SE) relative frequencies of playing, fighting behaviours and oral-nasal contact in focal animals.

Treatment	Age	Playing (%)	Fighting (%)	Oral-nasal contact (%)
WS		0.7 ± 0.18^{a}	0.8 ± 0.17	4.3 ± 0.38^{a}
RH		0.3 ± 0.10^{ab}	0.8 ± 0.13	2.9 ± 0.29^{b}
CF		0.2 ± 0.08^{b}	1.1 ± 0.19	5.5 ± 0.81^{a}
	1	0.8 ± 0.19^{A}	1.2 ± 0.17^{A}	6.3 ± 0.72^{A}
	2	0.3 ± 0.08^{B}	1.0 ± 0.15^{A}	3.9 ± 0.31^{B}
	3	0.1 ± 0.03^{B}	0.5 ± 0.15^{B}	2.4 ± 0.26^{C}

Differences shown within columns, for treatment: ^{a,b,c}; for age: ^{A,B,C}: $P < 0.05$.

Table 4 Mean (± SE) relative frequencies of localisation of focal pigs on the bedded area of the pen.

Treatment	Age	Relative frequency (%)
WS		66.3 ± 1.52^{a}
RH		57.5 ± 2.48^{b}
	1	55.0 ± 2.15^{A}
	2	58.8 ± 2.30^{B}
	3	72.0 ± 1.69^{C}
WS	1	62.0 ± 1.58^{y}
RH	1	48.0 ± 1.79^{z}
WS	2	64.5 ± 3.24^{y}
RH	2	53.0 ± 1.67^{z}
WS	3	72.6 ± 1.03
RH	3	71.5 ± 3.33

Differences shown within columns, for treatment: ^{a,b,c}; for age: ^{A,B,C}; for treatment within age: ^{y,z}: $P < 0.05$.

data from the deep-bedding and concrete floor systems were compared: total average daily feed intake ($P < 0.12$), total average daily weight gain ($P > 0.04$); total average daily feed conversion ($P < 0.3$); carcase weight ($P < 0.21$); bacon depth (mm) ($P < 0.1$); loin depth ($P < 0.07$); total average daily water intake ($P < 0.12$). Although skin lesions were not recorded in this study, no animal had to be treated or removed from the experiment due to injury. Tail biting was detected 18 times in CF, eight times in RH and nine times in WS, out of the 360 scans carried out per group.

There were no interactions or major effects of treatments or period of the study for the four climatic variables considered (dry bulb temperature, black globe temperature, relative air humidity and wind speed), or the values of floor surface temperature. Average black globe temperatures

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Table 5 Mean (± SE) performance of pigs reared on deep bedding with wood shavings, deep bedding with rice husks or concrete flooring.

Variables	Wood shavings	Rice husks	Concrete flooring
Initial live weight (kg)	20.9 ± 0.8	20.9 ± 0.7	20.8 ± 0.8
Live weight at 123 days (kg)	61.9 ± 0.9	62.1 ± 2.1	65.1 ± 0.5
Live weight at 183 days (kg)	111.9 ± 0.8	111.5 ± 2.9	116.4 ± 1.2
Carcase weight (kg)	81.6 ± 0.5	81.8 ± 2.6	84.9 ± 1.5
Bacon depth (mm)	17.6 ± 0.1	18.0 ± 1.2	19.7 ± 0.6
Loin depth (mm)	58.2 ± 0.8	57.8 ± 1.3	55.4 ± 0.5
Percentage of dry meat in carcase 24 h post slaughter	57.3 ± 0.2	57.0 ± 1.0	55.4 ± 0.4
Daily weight gain from 60–123 days (g)	650.3 ± 11.6	653.8 ± 23.5	703.4 ± 10.7
Daily weight gain from 124–183 days (g)	833.9 ± 9.6	823.1 ± 27.1	855.0 ± 14.1
Daily weight gain from 60–183 days (g)	739.8 ± 3.0	736.4 ± 17.9	777.4 ± 10.7
Daily feed intake from 60–123 days (g)	1,625.0 ± 32.1	1,580.7 ± 66.1	1,707.6 ± 25.4
Daily feed intake from 124–183 days (g)	2,390.3 ± 96.5	2,312.7 ± 111.0	2,586.3 ± 79.9
Daily feed intake from 60–183 days (g)	1,905.8 ± 81.0	1,831.3 ± 148.9	2,100.6 ± 36.9
Feed conversion from 60–123 days (g/g)	2,500.7 ± 57.8	2,419.0 ± 66.1	2,430.7 ± 70.1
Feed conversion from 124–183 days (g/g)	2,867.4 ± 120.7	2,811.7 ± 114.5	3,024.1 ± 68.3
Feed conversion from 60–183 days (g/g)	2,575.8 ± 107.9	2,480.6 ± 167.9	2,704.2 ± 67.0
Daily water intake at feeder from 60–183 days (g)	3,635.6 ± 397.5	3,434.8 ± 656.3	3,714.6 ± 261.1
Daily water intake at drinker from 60–183 days (g)	2,696.1 ± 755.7	2,931.6 ± 761.9	3,460.7 ± 149.0

Except for feed intake and conversion and water intake, where data refers to each pen, all data are the mean of 16 animals in each pen per treatment.

were 24.1, 27.2 and 22.3ºC, on the first, second and third period, respectively ($P < 0.01$). Temperatures throughout the experimental period ranged from 8.0 to 32.8ºC. Average maximum and minimum temperatures differed in the third compared with the other two periods (average maximum: 27.0 [± 0.5], 28.1 [± 0.4] and 23.9 [± 0.6]ºC; average minimum: 20.6 [± 0.5], 21.2 [± 0.3] and 15.5 [± 0.7]ºC, on the first, second and third period, respectively; $P < 0.01$).

Surface temperature differed in all three periods of observation ($P < 0.01$): it was milder in the initial period (22.6 [± 0.4]ºC), increased in the middle (27.9 [± 0.3]ºC), to decrease again at the end of the study (26.1 [± 0.5]ºC). Among treatments, there were also differences ($P < 0.01$): CF pens showed lower mean surface temperatures (24.9 [± 0.6]ºC) than both beddings (WS beddings 26.3 [± 0.6]ºC and RH bedding 25.6 [± 0.6]ºC). Relative humidity in beds was 89.5 (± 1.7)% in WS bedding and 85.2 (± 2.3)% in RH bedding ($P < 0.03$).

There was an interaction between the effects of treatment and period on skin temperature ($P < 0.001$); the skin temperatures differed between treatments at 1500h (similar between WS = 34.8 ± [0.22ºC], RH = 34.0 [± 0.23]ºC, and higher in CF = 32.8 [± 0.3]ºC; $P < 0.01$), but not at 0900h (WS = 30.6 [± 0.22]ºC, RH = 30.5 [± 0.27]ºC, and higher in CF 30.4 [± 0.22]ºC). The skin temperature was higher ($P < 0.01$) for pigs reared on bedding (WS = 32.5 [± 0.45]ºC, RH = 32.2 [± 0.5]ºC than on the CF (31.7 [± 0.3]ºC).

Discussion

Pigs kept in bedded pens displayed higher frequencies of playing and lower frequencies of peer-directed behaviours and idling than pigs reared in barren, concrete-floored pens. These findings corroborate several previous studies (eg Fraser *et al* 1991; Kelly *et al* 2000; van de Weerd *et al* 2005; Scott *et al* 2006b) that show the welfare of pigs housed in intensive confinement can be improved with the use of substrate. Creating the opportunity to perform highly-motivated, innate behaviours associated with foraging and inducing play behaviour, which is an expression of positive emotions (Spinka 2006), are two main mechanisms whereby the availability of substrate contributes to improve welfare.

When both substrates were compared, performance and meat quality were found to be similar in bedded pens with either wood shavings or rice husks. Some differences, though, were found in the behaviour of the animals reared with the two substrates. Compared to pigs kept on the rice husks, those in the wood-shavings pens were found located on the bedded area of the pen for a larger proportion of time. Because neither the time spent feeding nor feed consumption differed between the two treatments, this cannot account for the animals' choice of location. Alternatively, the wood shavings may be more attractive than rice husks as a source of rooting, or more comfortable for resting idly. The pigs housed in the wood-shavings pens also spent more time standing, played more and were less time idling than those kept in the rice-husk pens. On the other hand, despite

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the superiority of the wood-shavings substrate in inducing 'recreational' behaviours that are thought to increase welfare (Fraser *et al* 1991), pig-directed behaviours were more frequent than in the rice-husk bedding during the period following group formation. A possible explanation for this is that the wood-shavings bedding, by promoting higher overall levels of activity in the animals, may have led indirectly to more frequent social encounters, consequently increasing the probability of pig-directed behaviours, particularly in the period when the animals were establishing a social order. In fact, as pigs grew and adapted to the new social and spatial environment, both known sources of stress (Puppe *et al* 1997), these behaviours decreased.

Both rice husks and wood shavings seem to comply with several of the characteristics necessary to maintain the interest of animals for a relatively long period, such as being ingestible, chewable, odorous and rootable (van de Weerd *et al* 2003). Indeed, rooting did not decrease between 124 and 183 days of age, demonstrating a sustained interest from the animals. Considering that differences in the behaviour of pigs reared in the two substrates were small and transitory, these results suggest that both substrates are suitable bedding materials.

As van de Weerd *et al* (2005) and Scott *et al* (2006a) observed, the frequency of substrate manipulation decreased from the time of group formation to slaughter. In fact, several behaviours observed in this study showed the same pattern, resulting in higher frequencies of inactivity and lying behaviour at the end of the experiment. The change towards inactivity may be explained by the loss of novelty of the elements of the environment, including the material available for rooting (Pedersen *et al* 2005), the learning process involved in the exploration of the environment — including both the substrate and pen peers — and the maturational and physical growth of the animals.

Behavioural variables that could indicate differences in pigs' thermal comfort did not differ between treatments with and without bedding. Although floor temperature and pigs' skin temperature were higher in the pens with bedding than concrete flooring, these differences were modest and did not appear to result in differences in behaviours that could be attributed to the thermal comfort of the animals. For example, it has been shown that, at high temperatures, pigs reduce their time feeding (Collin *et al* 2001), but feeding behaviour did not differ between treatments. Furthermore, no treatment differences in the time spent lying accompanied temperature differences among periods or treatments as would be expected if these influenced the animals' thermal comfort (eg Hyun *et al* 2005). Fraser (1985) found that while under cool conditions growing pigs prefer to lie on straw, at higher temperatures they prefer bare floors. Hence, if temperature at any time was high enough to affect the thermal comfort of the animals in this study, we would also expect to see changes in the choice of location of the pigs reared in bedded pens, according to changes in temperature. Instead, as temperatures increased from the first to the second phase of observations, pigs were increasingly found lying and located in the bedded, as opposed to the concrete area. In conclusion, based on behaviours observed in this study, deep bedding can be presented as an alternative to improve the welfare of pigs reared in regions with summer conditions such as those reported in this study.

Previous studies found no differences in the frequencies of gastric ulcers, pneumonia and atrophic rhinitis (Amaral *et al* 2006) or in the growth and feed conversion (Cordeiro *et al* 2007) in pigs reared on deep bedding with rice husks or wood shavings during the spring months, in the same experimental station where this study was carried out. In the present study, weight gain, feed intake and conversion and fatness were 5 to 8% higher, while the percentage of meat in the carcase was about 3% lower in the pigs reared on concrete flooring. These differences may be associated with the small differences in climatic variables described; additionally, other factors might play a role, such as increased energy expenditure associated with higher levels of activity and a reduction in feed intake in pigs reared in bedded pens, which might be explained by the fact that in this system pigs can direct their foraging motivation to the substrate. The economic results of the system for the local industry require a more extensive analysis. This needs to include issues such as differences in the cost of housing, the added cost of substrates and labour, and possible premium prices that might be obtained by differentiated products with perceived added ethical value. In this respect, of special interest should be an identification of current demand, both locally and internationally, for a product that addresses consumers' concerns regarding animal welfare along with the social, human health and environmental impacts of pork production.

In conclusion, the present experiment, which was carried out during the hottest months of summer — the most critical season for pigs in subtropical regions — presents behavioural data that allow us to conclude that both substrates tested — abundant and readily available in the region — are equally suitable for bedding.

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