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Effect of floor type on the growth performance and health status of growing-finishing pigs

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Abstract

Using a factorial design: two full floor types, concrete *vs.* concrete waterproofed with resin (resin floor) and two slat types, concrete *vs.* metal, were used to house 72 pigs in four rooms (18 pigs room^{-1}). During the experimental period which lasted from 22.9 kg to 112.7 kg live weight the four groups of pigs received the same feed. Growth, water consumption and health status of the pigs as well as subjective odour level inside the rooms were studied. The resin floor with metal slats tended ($P < 0.1$) to improve feed conversion efficiency and positively affected ($P < 0.03$) pig health. In the room with the resin floor and metal slats odour level was significantly lower than in the other three rooms. The potential predictive function for the relationship between average daily water consumption (WC, in L) and feed average daily intake (FADI, in kg) is $WC = 2.692 \times FADI^{1.265}$. Odour level increased with pig live weight. The use of resin as an impermeable floor material is promising for housing growing, finishing pigs.

Additional key words: odour level, production results, resin floor, sanitary status, water consumption.

Resumen

Efecto del tipo de suelo sobre los resultados productivos y estado sanitario de cerdos en crecimiento y acabado

Bajo un tratamiento factorial: dos tipos de suelo, hormigón *vs* hormigón impermeabilizado con resina (suelo de resina) y dos tipos de rejilla, hormigón *vs* metálica, 72 cerdos fueron alojados en cuatro salas (18 cerdos por sala). Durante el periodo experimental, comprendido entre 22,9 y 112,7 kg de peso vivo los cuatro grupos de cerdos recibieron el mismo tipo de pienso. Se estudió el crecimiento, el consumo de agua y el estado sanitario de los cerdos, así como el nivel subjetivo de olor en el interior de las salas. El suelo de resina y la rejilla metálica tendieron ($P < 0,1$) a mejorar el índice de transformación del alimento y afectaron positivamente, a un nivel significativo ($P < 0,03$), al estado sanitario de los cerdos. En la sala de suelo de resina y rejilla metálica el nivel de olor fue significativamente más bajo que en las restantes. La relación entre el consumo de agua y de pienso se ajustó a una función potencial. El nivel de olor aumentó con el peso vivo de los cerdos. La utilización de resina como material impermeabilizante del suelo es prometedora para los alojamientos de cerdos de cebo.

Palabras clave adicionales: consumo de agua, nivel de olor, resultados productivos, sanidad, suelo de resina.

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Abbreviations used: ADG (average daily gain), FADI (feed average daily intake), FCE (feed conversion efficiency), ME (metabolizable energy), SEM (standard error of mean), WC (water consumption).

Introduction

Previous experiments have demonstrated that floor type used in pig housing affects the behaviour, welfare and health status of the animals (Hoofs, 1991; Aarnink *et al*., 1997). Consequently, production can be affected (Saoulidis *et al*., 2000). However, other authors (Anderson *et al*., 1998; Corino *et al*., 2003; Philippe *et al*., 2006) did not observe significant effects of floor type on pig production results.

In Europe, new legislation on environmental protection requires a reduction in ammonia emission and odour from pig housing, and floor type can influence ammonia emission and odour (Berckmans *et al*., 1998; Breuer *et al*., 2002; Navarotto *et al*., 2002).

Recently resin has started to be used to waterproof the floor of the Spanish pig houses. To our knowledge, no experiments have studied whether the use of resin has a positive effect on production (ADG and FCE), health status and irritating, stinking gas production compared with conventional concrete floors. The aim of this experiment was to study these aspects using growing-finishing pigs.

Material and methods

The 72 animals used in this experiment were (Duroc x Pietrain) x (Large White x Landrace) barrows from the same farm with an initial mean weight of 22.91 ± 2.11 kg. The pigs were housed in a facility that included four rooms with six equal size pens. All pens had 40% slat surface. The rooms differed in the full floor type: conventional concrete (from now on concrete) *vs.* concrete waterproofed with a 3 mm of thick resin layer (from now on resin) and slat (concrete *vs.* metal).

The experiment had a factorial design with blocks: one room with a concrete floor with concrete slats; one room with a concrete floor with metal slats; one room with resin floor with concrete slats and a final room with a resin floor and metal slats. Each room contained 6 replicates with 3 pigs replicate^{-1}.

Initial pig weight by replicate, was equalised as much as possible. Pigs were fed three commercial cereal-soybean based feeds: from the beginning of the experiment to 60 kg live weight the feed contained 3,250 kcal ME kg^{-1}, 16.6% crude protein and 0.90% lysine; from 60 to 100 kg live weight 3,200 kcal ME kg^{-1}, 15.2% crude protein and 0.75% lysine and from 100 kg live weight to slaughter weight 3,200 kcal ME kg^{-1}, 14% crude protein and 0.60% lysine. Slaughter mean weight was 112.75 ± 8.32 kg. The pigs were weighed at days 0 (beginning of the experiment), 23, 72 and 114 (end of the experiment) and the feed consumption was determined per replicate. In each room daily water consumption was measured with a water meter. Pig health status was estimated by recording the number of antibiotic treatments. Pigs that showed apathy, diarrhoea or were coughing were given antibiotics. The irritating odour and stinking gas in the four rooms were estimated daily by two observers using an increasing range of odour from 0 to 3 (0 = no odour, 1 = very light odour, 2 = light odour, 3 = appreciable odour). Available surface pig^{-1} was 2.4 m^2. The minimum and maximum temperatures in each room controlled daily using a maximum-minimum thermometer. Each room had the same cooling and ventilation system. Each pen had one wet-dry feeder placed on full floor and two drinking troughs placed at 30 cm above slats.

The results were subjected to analyses of variance and covariance. Minimum and maximum temperatures were analysed by variance analysis with a model that included only the room as the main factor. For the dependent variables average daily gain (ADG), feed average daily intake (FADI), feed conversion efficiency (FCE) and pig health status. The main variables were full floor and slat type and their interaction. The covariate pig initial weight was included in the statistical model for the independent variables, ADG, FADI and FCE, but when the covariate was not significant ($P > 0.05$), it was discarded. For subjective odour estimation variation in the factors considered were the room and phase of the experiment (0-23, 23-72 and 72-114 d), and their interaction. For variables ADG, FADI, FCE and health status the experimental unit considered was the replicate; however room was the experimental unit in the studies of the variables minimum and maximum temperatures and odour level. To quantify the relationship between average daily water consumption and FADI a simple regression equation was calculated. All analyses were carried out using the statistical package SG-Centurion (Statgraphics).

Results and discussion

Minimum and maximum average temperatures recorded during the experiment, in each room, are shown in Table 1. Room did not have a significant effect on aver-

Table 1. Minimum and maximum average temperature recorded during the experiment according to floor and slat type (mean ± standard deviation)

Room	Floor	Slat	T_{min} (ºC)	T_{max} (ºC)
1	Concrete	Concrete	18.23 ± 2.74	24.56 ± 2.70
2	Concrete	Metal	18.17 ± 2.64	24.54 ± 2.78
3	Resin	Concrete	18.36 ± 2.44	24.60 ± 2.98
4	Resin	Metal	18.44 ± 2.54	25.23 ± 3.53

There was no significant difference ($P > 0.05$) among rooms.

age minimum and maximum average temperatures. This was expected because the number of pigs and the cooling and ventilation systems in each room were the identical throughout the experiment.

The effect of floor and slat type on growth performance is shown in Table 2. The resin floor had a positive influence on pig ADG from the start of the experiment to 23 days later. During this phase pigs lodged on the resin floor with concrete slats had a ($P < 0.10$) higher ADG that the other groups of pigs. There was a significant interaction ($P < 0.019$) between floor and slat type for overall ADG and slaughter weight. Metal slats had a positive effect on the same variables in pigs raised on the concrete floor. This was not detected in pigs housed on the resin floor. The covariate initial pig weight had a significant ($P < 0.015$) effect on ADG. As pig initial weight increased the ADG also increased during the periods 0-23, 23-72 and 0-114 d. During these growth phases, the coefficients of partial regression between initial weight and ADG were 23.93, 27.34 and 16.42 g kg^{-1} respectively.

The FADI and FCE according to floor and slat type are shown in Table 3. Pigs lodged on resin floor tended ($P < 0.084$) to have higher FADIs from the beginning of the experiment to 23 days later. Overall the FCE tended ($P < 0.10$) to be lower in pigs lodged on a concrete floor and with concrete slats compared to the other three pig groups. Initial pig weight had a significant effect on FADI. For the phases 0-23, 23-72, 72-114 and 0-114 days, the coefficients of partial regression between

Table 2. Effect of floor and slat type on pig growth performance

Variation	N	W_0 (kg)	W_{23} (kg)	W_{72} (kg)	W_{114} (kg)	ADG (g)			
						0-23	23-72	72-114	0-114
Floor type									
Concrete (C)	12	22.82	32.72^{a}	72.05	110.59	426.21^{a}	802.69	940.56	775.93
Resin (R)	12	23.01	34.56^{b}	75.53	114.91	506.40^{b}	836.02	960.20	814.14
Slat type									
Concrete (C)	12	22.73	34.35	73.48	109.82	497.29	798.55	887.07	769.05
Metal (M)	12	23.10	32.93	74.09	115.69	435.32	840.16	1013.72	821.02
SEM		1.11	0.59	1.93	2.63	25.50	29.80	64.00	23.30
Interactions									
C x C	6	22.66	33.14	71.46	102.92^{a}	444.65	782.03	768.31^{a}	708.00^{a}
C x M	6	22.97	32.29	72.64	118.27^{b}	407.76	823.35	1112.80^{b}	843.87^{b}
R x C	6	22.80	35.56	75.50	116.72^{b}	549.92	815.07	1005.76^{b}	830.11^{b}
R x M	6	23.23	33.56	75.55	113.12^{ab}	462.87	856.98	914.63^{b}	798.17^{ab}
SEM		1.57	0.831	2.73	3.72	36.10	42.11	90.51	32.96
P floor		0.90	0.039	0.22	0.26	0.039	0.44	0.83	0.26
P slat		0.82	0.10	0.82	0.13	0.10	0.37	0.18	0.13
P floor x slat		0.96	0.49	0.84	0.019	0.49	0.99	0.026	0.019
P covariate W_0			0.0001	0.0001	0.0001	0.0001	0.0039	0.75	0.015

N = number of replicates (3 pigs $replicate^{-1}$). W_0 = initial weight. W_{23} = weight at 23 d. W_{72} = weight at 72 d. W_{114} = weight at 114 d (slaughter). ADG = average daily gain. SEM = standard error of mean. Means with different superscripts are significantly different ($P < 0.05$).

Table 3. Influence of floor and slat type on average daily feed intake (FADI) and feed conversion efficiency (FCE**)**

Variation	N	FADI 0-23 (kg)	FADI 23-72 (kg)	FADI 72-114 (kg)	FADI 0-114 (kg)	FCE 0-23 ($kg\ kg^{-1}$)	FCE 23-72 ($kg\ kg^{-1}$)	FCE 72-114 ($kg\ kg^{-1}$)	FCE 0-114 ($kg\ kg^{-1}$)
Floor type									
Concrete (C)	12	0.892	1.99	3.54	2.33	2.19	2.46	4.55	3.05
Resin (R)	12	0.980	1.94	3.40	2.27	1.96	2.31	3.55	2.77
Slat type									
Concrete (C)	12	0.964	1.97	3.50	2.32	2.03	2.46	4.63	3.05
Metal (M)	12	0.907	1.96	3.44	2.28	2.13	2.31	3.47	2.76
SEM		0.034	0.083	0.14	0.082	0.095	0.078	0.55	0.11
Interactions									
C x C	6	0.926	1.98	3.52	2.32	2.24	2.51	5.77	3.34
C x M	6	0.857	2.00	3.56	2.33	2.14	2.40	3.32	2.77
R x C	6	1.003	1.96	3.47	2.32	1.81	2.40	3.48	2.77
R x M	6	0.957	1.93	3.32	2.24	2.12	2.22	3.61	2.76
SEM		0.048	0.12	0.19	0.11	0.13	0.11	0.78	0.16
P floor		0.084	0.70	0.47	0.64	0.10	0.20	0.21	0.095
P slat		0.25	0.96	0.78	0.77	0.45	0.20	0.15	0.089
P floor x slat		0.81	0.85	0.63	0.72	0.14	0.74	0.11	0.10
P covariate W_0		0.0001	0.0001	0.028	0.0001	0.20	0.0001	0.54	0.018

N = number of replicates (3 pigs $replicate^{-1}$). SEM = standard error of the mean.

initial weight and FADI were 51.12, 115.31, 65.82 and 84.28 g kg^{-1}, respectively. A similar influence of pig initial weight on ADG and FADI was reported by Daza *et al.* (2003).

Average daily water consumption pig^{-1} according to room and experimental phase is shown in Table 4. In the room with a resin floor and concrete slats water consumption was higher than in the other rooms. This may be due to higher waste of water. As expected, water consumption increased with pig live weight and feed intake. According to the room x period interaction results, the average daily water consumption from 23 to 73 d and from 73 to 114 d was higher in the room with a resin floor and concrete slats than in the other rooms. The relationship between average daily water consumption (WC in litres) and FADI (in kg) gave a potential function of the form:

$$WC = 2.692 \times FADI^{1.265} \ (R^2 = 0.975, RSD = 0.119, P < 0.0001).$$

There is little published information on water consumption in pig production. The results of this experiment are in accordance with data from Whittemore (1993), INRA (1984) and Uremovic *et al*. (2000).

The positive effect of the resin floor on pig production can be attributed to the fact that the resin is impermeable that, in our experiment, improved pig health status (Table 5) and decreased irritating, stinking gas emission (Table 6).

Hoofs (1991) found that metal slats improved pen cleanliness, overall pig performance and reduced veterinary treatments. However, other studies (Anderson *et al*., 1998; Corino *et al*., 2003; and Philippe *et al*., 2006) did not observe a significant effect of floor type on production of growing-finishing pigs.

In our experiment, the resin floor was more easily cleaned than the concrete floor. According to Kreis *et al.* (1998), best production results come from floors which are easily cleaned which ensured animal comfort.

The influence of floor and slat type on pig health status is shown in Table 5. The average total number of antibiotic treatments $replicate^{-1}$ was significantly higher in pigs lodged on a concrete floor or with concrete slats. Pigs that had the best health status were those lodged on the resin floor with metal slats. Hoofs (1991) and Saoulidis *et al*. (2000) also observed a positive relationship between production results and pig health status.

Table 4. Water consumption according to room and experiment phase

Variation factor	N	Water consumption (L)
Room		
Concrete floor and concrete slat (CC)	114	7.20[a]
Concrete floor and metal slat (CM)	114	6.67[a]
Resin floor and concrete slat (RC)	114	8.31[b]
Resin floor and metal slat (RM)	114	7.21[a]
SEM		0.20
Phase		
0-23 days (1)	92	2.51[a]
23-72 days (2)	196	6.09[b]
72-114 days (3)	168	13.45[c]
SEM		0.16
Interactions		
CC x 1	23	2.78[a]
CC x 2	49	5.94[b]
CC x 3	42	12.86[cf]
CM x 1	23	2.45[a]
CM x 2	49	5.50[b]
CM x 3	42	12.07[c]
RC x 1	23	2.41[a]
RC x 2	49	6.87[d]
RC x 3	42	15.66[e]
RM x 1	23	2.41[a]
RM x 2	49	6.87[b]
RM x 3	42	15.66[f]
SEM		0.31
P room		0.0001
P phase		0.0001
P room x phase		0.0001

N = number of observations (d), SEM = standard error of mean. Means with a different superscript are significantly different ($P < 0.0001$).

Estimation of odour level according to room and experimental phase is presented in Table 6. The odour level estimate was higher in rooms with a concrete floor and concrete slats. As expected, odour level increased significantly with pig live weight. The room x experimental phase interaction shows there was a higher odour level in rooms with a concrete floor and concrete slats at the end of the pig finishing period.

Ammonia emission and odour level are variables which are positively correlated (Mol and Ogink, 2004; Hayes *et al*., 2006). According to Aarnink *et al.* (1997), the use of metal slats instead of concrete slats reduced ammonia volatilization, caused less fouling of the solid floor and less ammonia emission. Saoulidis *et al*. (2000) and Navarotto *et al.* (2002) also observed that concrete floors gave a higher ammonia concentration than a slatted floor and that this finding led poorer health status and growth performance of growing-finishing pigs. Dirty concrete floors may produce more ammonia slatted floors. Kavolésis (2005) observed that in slatted and concrete floor system, the ammonia emission rate was 2.2 and 2.8 kg pig^{-1} yr^{-1} respectively. Pelletier *et al*. (2005) studied gas and odour emissions produced by 11 different materials commonly used in pig housing. Highest ammonia emission was produced by normal concrete, which reached a maximum of about 175 mg m^{-2} h^{-1}.

It is concluded that the use of resin as an impermeable material of floors for pig housing is promising for growing and finishing pigs.

Table 5. Effect of floor and slat type on pig health status

Variation factor	N	Antibiotic treatments 0-23 days	Antibiotic treatments 23-72 days	Antibiotic treatments 72-114 days	Total antibiotic treatments 0-114 days
Floor type					
Concrete (C)	12	1.75[a]	5.25	0.58[a]	7.58[a]
Resin (R)	12	0.75[b]	5.83	0.00[b]	6.58[b]
Slat type					
Concrete (C)	12	1.00	7.75[a]	0.50	9.25[a]
Metal (M)	12	1.50	3.33[b]	0.08	4.91[b]
SEM		0.25	0.37	0.17	0.33
Interactions					
C x C	6	1.00[a]	7.50	1.00	9.50[a]
C x M	6	2.50[b]	3.00	0.17	5.67[b]
R x C	6	1.00[a]	8.00	0.00	9.00[a]
R x M	6	0.50[a]	3.66	0.00	4.16[c]
SEM		0.35	0.52	0.24	0.50
P floor		0.01	0.28	0.02	0.03
P slat		0.17	0.0001	0.09	0.0001
P floor x slat		0.01	0.87	0.09	0.20

N = number of replicates (3 pigs replicate^{-1}). SEM = standard error of the mean. Means with a different superscript are significantly different ($P < 0.03$).

Table 6. Estimated odour level according to room and experimental phase

Variation factor	N	Odour level
Room		
Concrete floor and concrete slat (CC)	114	1.52[a]
Concrete floor and metal slat (CM)	114	1.40[b]
Resin floor and concrete slat (RC)	114	1.17[c]
Resin floor and metal slat (RM)	114	1.08[c]
SEM		0.041
Phase		
0-23 days (1)	92	0.10[a]
23-72 days (2)	196	1.35[b]
72-114 days (3)	168	2.44[c]
SEM		0.033
Interactions		
CC x 1	23	0.22[a]
CC x 2	49	1.43[b]
CC x 3	42	2.93[c]
CM x 1	23	0.087[a]
CM x 2	49	1.43[b]
CM x 3	42	2.69[d]
RC x 1	23	0.043[a]
RC x 2	49	1.37[b]
RC x 3	42	2.09[e]
RM x 1	23	0.043[a]
RM x 2	49	1.16[f]
RM x 3	42	2.05[e]
SEM		0.067
P room		0.0001
P phase		0.0001
P room x phase		0.0001

N = number of observations (days), SEM = standard error of mean. Means with a different superscript are significantly different ($P < 0.0001$).

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