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Effects of rearing system on performance, animal welfare and meat quality in two pig genotypes

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Abstract

The effects of an alternative rearing system (O) for growing-finishing pigs (sawdust-shave bedding with free outdoor access, 2.4 m²/pig) compared to a conventional (C) one (slatted floor, 0.65 m²/pig) were evaluated for performance, animal welfare and meat quality in two (Duroc or synthetic line crossbreds) genotypes. Trials were conducted in spring and winter, each involving one pen of 10 pigs / genotype / system (a total of 40 pigs / season).

No significant interactions between rearing system and genotype were observed on any of the traits evaluated. On the whole, the O pigs spent 40% more time on exploratory activities, in particular towards the bedding, suggesting an improved animal welfare with the O system. Urine levels of cortisol and catecholamines in the O were similar with those in C pigs at 70kg. The O pigs exhibited a 6% increase in growth rate and were 5kg heavier at slaughter at the same age. Back fat depth and lean meat content, as well as plasma ACTH and cortisol, and urine cortisol and catecholamines levels at slaughter were not significantly affected by the rearing system. The O pigs exhibited similar pH_1 and pHu values, higher drip losses, but also higher intramuscular fat contents. The O system improved loin juiciness, but did not influence other eating quality traits.

Introduction

Society concerns about conventional pig production have been increasing for a number of years. This production system is generally thought to be associated with a negative environmental impact (pollution, offensive odours), a poor animal welfare due to high animal densities and bad housing conditions, and could be involved in a reduced meat quality (Rainelli, 2001; Ngapo *et al.*, 2003). Thus, in the near future, the pork chain has to propose pig production systems that satisfy the consumer and citizen demands: lower environmental impact, better animal welfare and meat quality.

A previous comparative study on pig husbandry methods showed that sawdust-shave bedding with free outdoor access (2.4m²/pig) decreased the level of offensive odours, and improved animal welfare and health, growth performance and loin meat juiciness compared to the conventional system on slatted floor (Lebret *et al.*, 2003, 2004). However, the pig responses, in particular their stress reactions during slaughtering procedure and meat quality may also depend on pig genotype (Terlouw, 2005). Thus, another study was conducted, that aimed to evaluate the influence of husbandry method on performance, animal welfare and meat quality in two pig genotypes.

Materials and Methods

***Animals and husbandry*.** The experiment comprised a total of 80 (castrated males (CM) and females (F)) pigs from two genotypes: 40 synthetic line x (Large White x Landrace) crossbreeds (SL), and 40 Duroc x (Large White x Landrace) crossbreeds (D). Synthetic line is the P76 line (Pen Ar Lan breeding company, Maxent, France), issued from the Laconie (created from Hampshire, Pietrain and Large White) and Penshire (created from Hampshire, Large White and Duroc) lines. All pigs were free of the halothane-sensitive (n) and RN^- alleles. In each genotype, at the average live weight (LW) of 35kg, littermates were allocated to one of the two following systems. A conventional (totally slatted floor, 0.65 m²/pig, controlled ambient temperature at 22° C) system, considered as control (**C**), or

sawdust-shave bedding (1.3 m²/pig) with fluctuating ambient temperature, and with free access to an outdoor area (concrete floor, 1.1 m²/pig) (**O**). Pigs were fed *ad libitum* with a growing diet up to 70kg LW (2.35 Mcal/kg NE, 17.5 % crude protein, 0.85 % digestible lysine) and a finishing diet thereafter (2.35 Mcal/kg NE, 15.0 % crude protein, 0.72 % digestible lysine). Animals had free access to water.
Trials were conducted in spring and winter, each involving one pen of 10 pigs (5 CM and 5 F) per genotype and system (i.e. 40 pigs per season). For each replicate, pigs were reared in two different rooms (one per system) of the same building.

Behaviour and physiological observations. At the average LW of 70kg, the activities (resting, feeding, moving, explorations, fighting) and number of pigs implicated were evaluated every 10 minutes by analyses of video tapes recorded over 24 hours (De Oliveira *et al.*, 1999). Time-budgets (%) during daytime (8 am – 4 pm) were established for each system. At the same LW, after overnight fasting, urine was collected on each pig and stored at -80° C until assayed for cortisol, adrenaline and noradrenaline as previously described (Foury *et al.*, 2005).

Slaughter and carcass traits. Pigs were slaughtered at the experimental slaughterhouse of INRA, in groups of 5 pigs per pen, when the average LW of the group reached 110kg. Two groups, one from each rearing system but same genotype, were slaughtered on the same day. After overnight fasting, pigs were transported during 2 hours and kept in lairage for 3 hours without mixing the two groups, before slaughtering by electrical stunning and exsanguination.
At slaughter, blood was collected, centrifuged immediately and stored at –20° C before determination of plasma ACTH and cortisol using radioimmunoassays.
Carcass weight, mean back fat depth (mean of measurements taken at the $3^{rd}/4^{th}$ lumbar vertebra and the $3^{rd}/4^{th}$ last rib levels), muscle depth ($3^{rd}/4^{th}$ last rib level) and lean meat content (calculated from the linear carcass measurements) were recorded on the day of slaughter.

Meat quality traits. Twenty-five minutes after slaughter, samples of *Longissimus lumborum* (LL), *Biceps femoris* (BF) and *Semimembranosus* (SM) muscles were taken, immediately frozen in liquid nitrogen and stored at – 80° C before subsequent determination of pH_1 after homogenisation of 2g muscle in 18ml of 5mM iodoacetate buffer. The following day, transversal sections of LL, BF and SM muscles were taken for determination of ultimate pH (pH_u) and colour (coordinates CIE L*, a* and b* (triplicate measurements), chromameter Minolta CR 300). Muscles slices were then trimmed of external fat, minced and freeze-dried before determination of lipid content (Folch *et al*., 1957). The same day, three slices (1.5cm depth) of LL muscle were taken (last rib level), trimmed of external fat and perimysium, weighed and kept at 4° C in plastic bags for determination of drip losses at 2 and 4 days post-mortem (Honikel, 1998).

Sensory analyses. On all pigs from the winter replicate (n=40), a piece of the right loin of each carcass was taken the day after slaughter, trimmed of external fat and kept at 4° C for 3 subsequent days. They were then stored under vacuum and frozen at -20° C until sensory analyses performed at INRA-SRV. After thawing at ambient temperature, chops were grilled (double contact grill, 280° C for 6 minutes). Samples (muscle part of the deboned chop with the remaining external fat (3 to 5mm depth)) were assessed by a 10-member trained taste panel for odour (normal and abnormal odours of lean and fat), tenderness, juiciness, and typical and abnormal flavours. Ratings were subsequently scored from 0 (absent) to 10 (high). Four samples (one by rearing system and genotype) were evaluated per session. Individual panellist scores were averaged and mean scores from each sample were used for the statistical analysis.

Statistical analyses. Data of growth performance and carcass traits were submitted to an analysis of variance (GLM procedure, SAS), including the effects of husbandry method, genotype, replicate and sex, and their interactions (when significant). Slaughter date (intra-replicate and genotype) was included in the model for the data analysis of meat quality parameters. The influence of husbandry method on time-budgets during the rearing period was evaluated using a χ^2 test.

Results and discussion

No significant interactions between rearing system and genotype were observed on any of the traits evaluated. Consequently, only the main effects of rearing system are presented here.

Housing conditions

In the conventional system, the average ambient temperature was 22.2 ± 1.1° C. It was cooler, with higher fluctuations in O the system, in particular during the winter. During spring, it was: 17.8 ± 2.7° C and 15.0 ± 4.2° C in indoor and outdoor areas, respectively whilst during the winter season it was 15.2 ± 2.9° C and 6.8 ± 3.6° C in indoor and outdoor areas, respectively.

Behaviour and physiological observations during the rearing period

The analysis of time-budgets during daytime (8 am – 4 pm) indicates that the O pigs tended to exhibit more exploration activities than the C pigs (28 and 20% of the time, respectively, $p<0.10$) and spent less time resting (Figure 1). The pen walls and floor were the main substrates investigated by the pigs in both systems. The O pigs spent 35% of their exploratory time manipulating the bedding. Difference between O and C pigs in time spent in exploration behaviour towards other pigs did not reach significance (21% and 28% of time, resp^{ly}., $p>0.10$). The higher investigative behaviour of O pigs confirms previous findings (Lebret *et al*., 2004) and is in accordance with Lyons *et al.* (1995), de Oliveira et al. (1999) and Beattie et al. (2000), who reported a higher activity level of pigs reared on straw bedding compared with slatted floor. These findings suggest that the O system would improve pig welfare.

Concerning physiological observations, we observed similar levels in urine cortisol, adrenaline and noradrenaline (expressed relatively to creatinine concentration) in the O compared with those in C pigs at 70kg (Figure 2). This indicates that, in our experimental conditions, the production system did not modify the activity of the hypothalamic-pituitary-adrenocortical axis (assessed by cortisol) and the autonomic nervous system (assessed by catecholamines) during the rearing period. D crossbreeds tended to exhibit lower levels in urine cortisol compared with SL (18.5 and 24.9 ng/mg creatinine, resp^{ly}., $p=0.07$), whereas levels of catecholamines were not affected by pig genotype ($p>0.10$).

Growth performance

The husbandry method influenced significantly the growth performance of animals. Compared with the C pigs, the O pigs ate 10% more and grew 6% faster during the growing-finishing period, and were thus 5kg heavier at slaughter (Table 1). SL and D crossbreeds exhibited similar average growth performance (not shown). Feed conversion ratios were similar between groups during both growing and finishing periods. The lower ambient temperature in the O system may explain the higher feed intake of these animals and consequently, their higher growth rate. This is in agreement with the well-established effects of ambient temperature on growth performance of *ad libitum* fed pigs (Le Dividich *et al*., 1998). The decreased competition among pigs, resulting from the increased space allowance, could also be involved in this phenomenon. Our results are in accordance with previous findings (Lebret *et al*., 2004), and with those of Lyons *et al.* (1995), Beattie *et al.* (2000) and Lebret *et al.* (2002), who reported better growth performances of pigs reared in straw-bedded pens or offered an outdoor access.

Carcass traits

The pig rearing system did not significantly affect carcass traits. Muscle and mean back fat depths and lean meat content were similar between O and C pigs ($p>0.10$, Table 1). No significant seasonal effects were noticed on these traits. Carcass dressing and drip losses, as well as proportions of wholesale cuts, were not affected by the pig rearing system. We noticed higher average proportions of loin (+ 1.5 point, $p<.001$) and backfat (+ 0.7 point, $p<.01$), and lower proportions of belly ($p<.01$) and shoulder ($p<.05$) for pigs reared during the winter compared with those reared during the spring season. Influence of pig genotype on average lean meat content did not reach statistical significance (59.0 and 59.7 % D and SL crossbreds, respectively, $p=0.13$). The lack of any significant effect of the rearing system on carcass fatness and composition is in accordance with the results of Van der Wal *et al.* (1993), Lyons *et al.* (1995) and Lebret *et al.* (2002) for pigs reared on straw bedding and/or with outdoor access compared with conventional system. By contrast, we previously reported an increased carcass fatness of synthetic line crossbreds pigs reared in the O compared to the C system (Lebret *et al.*, 2004), in agreement with Beattie *et al.* (2000) for pigs reared on straw bedding. This suggests that different factors, such as climatic conditions and pig genotype, may also influence the deposition of muscle and fat depending on the husbandry system.

Physiology at slaughter and meat quality

The O pigs exhibited similar levels to the C pigs in urine cortisol and catecholamines (Figure 2), blood ACTH and cortisol, and LL and BF rates of post-mortem pH decline (pH_1), but had lower pH_1 values than the C pigs (Table 2) in the SM ($p<0.05$). Altogether, this indicates that, in our experimental conditions, the husbandry method did not influence the physiological response of pigs to stress at slaughter (Warriss *et al*., 1983; Terlouw, 2005). This gave rise to similar (LL and BF) patterns of post-mortem metabolism in both groups. These results confirm previous findings (Lebret *et al*., 2003) and are in agreement with many other studies that did not report any significant difference in saliva (assessed at the end of the lairage period) and/or plasma (assessed at slaughter) cortisol concentrations (Geverink *et al.*, 1999; Klont *et al.*, 2001). Most of the studies did not report significant effects of indoor enriched *vs.* conventional system on pH_1 in the LL, SM or BF muscles (Van der Wal et al., 1993; Geverink et al., 1999; Beattie et al., 2000; Klont et al., 2001). Ultimate pH was not significantly affected by the rearing system in the three muscles under study, in contrast to the lower ultimate pH previously noticed in the SM and BF of the O compared with C pigs (Lebret *et al.*, 2003). The present results agree with most studies (Geverink *et al.*, 1999; Beattie *et al.*, 2000, Lebret *et al.*, 2002 for LM and/or SM muscles), whereas Van der Wal *et al.* (1993) noticed lower LM pHu for "enriched" pigs. Compared with the SL, the D crossbreeds exhibited lower blood ACTH level (92.4 *vs* 154.9 pg/ml for D and SL pigs, $resp^{ly}$., $p<0.05$), in accordance with tendency to lower basal urinary cortisol (above). The D pigs had higher urine adrenaline concentration than the SL (8.4 *vs* 6.3 ng/mg creatinine, $resp^{ly}$., $p<0.01$), but similar muscle pH_1 and pH_u values.

Meat colour was modified by the rearing system, with higher yellowness (b* value) in the three muscles, higher redness (a* value) in the BF and SM, and slightly higher lightness (L*) ($p<.10$) in the LM and BF of the O compared with the C pigs. This confirms previous findings (Lebret *et al.*, 2003). Other studies generally show that LL colour usually remains unaffected by the rearing method (Van der Wal *et al.*, 1993; Geverink *et al.*, 1999; Beattie *et al.*, 2000; Klont *et al.*, 2001). The increased meat redness and yellowness in ham muscles may be explained by the outdoor access of pigs, in agreement with Bee *et al.* (2004). The O husbandry method led to higher LL drip losses at 2 and 4 days *post-mortem* despite the lack of any significant influence of the husbandry method on pH_1 and pH_u values in that muscle, in accordance with previous results. By contrast, others studies usually reported no significant effect (Van der Wal *et al.*, 1993; Geverink *et al.*, 1999; Beattie *et al.*, 2000), or lower (Klont *et al.*, 2001) LL drip loss with enriched housing conditions. Drip loss and meat colour scores were similar ($p>.05$) in both pig genotypes.

Intramuscular fat (IMF) content was increased in the 3 muscles of the O pigs, compared with the C. This effect was slightly more pronounced for the D than SL crossbreeds in the ham (BF and SM) muscles. On average, IMF in BF and SM was increased by 23% in the D and by 14% in the SL, but was similar (increasing by 24%) in the LM of both genotypes. On average, D exhibited higher IMF levels than SL crossbreeds, in the three muscles considered ($p<0.001$). The increase in IMF content in the O pigs confirms previous results (Lebret *et al.*, 2003). However, it is noteworthy that, in the present experiment, IMF increased independently of carcass fatness. A tendency for higher lipid content in the SM of pigs offered outdoor access has been reported (Lebret *et al*., 2002), whereas Van der Wal *et al.* (1993) did not show any significant effect of husbandry method on intramuscular fat.

Results from sensory analyses indicate that meat from the two rearing systems exhibited high levels of normal odour and flavour, and did not show any abnormal flavour (Figure 3). The O rearing system increased meat juiciness ($p<0.001$) but did not modify tenderness or flavour of meat. Meat from D was judged more tender than meat from SL pigs ($p<0.001$) whereas other eating traits were similar in both genotypes. The increased loin meat juiciness with outdoor rearing confirms previous results (Lebret *et al.*, 2004), and may have derived from its higher intramuscular fat content (Cannon *et al.*, 1995; Lebret *et al.*, 1999, for reviews).

Conclusion

The influence of rearing system on animal behaviour, performance, neuroendocrine system activity, carcass traits and meat quality did not differ between Duroc and synthetic line crossbreds. Present results confirm the improved animal welfare and growth performance with the O system. Carcass traits were unaffected by the pig rearing system. Physiological response of pigs to stress at slaughter was not influenced by the rearing system, giving rise to similar rates and extents of muscle

post-mortem pH decline (except a slightly lower pH_1 in the SM of O pigs). The O system led to higher meat redness and yellowness, higher LL drip losses, but also higher intramuscular fat content. Loin meat juiciness was improved with the O compared with the conventional rearing system. Finally, present results indicate that both SL and D crossbreeds can be used in the enriched rearing system presented here, but D crossbreeds will lead to higher meat eating quality.

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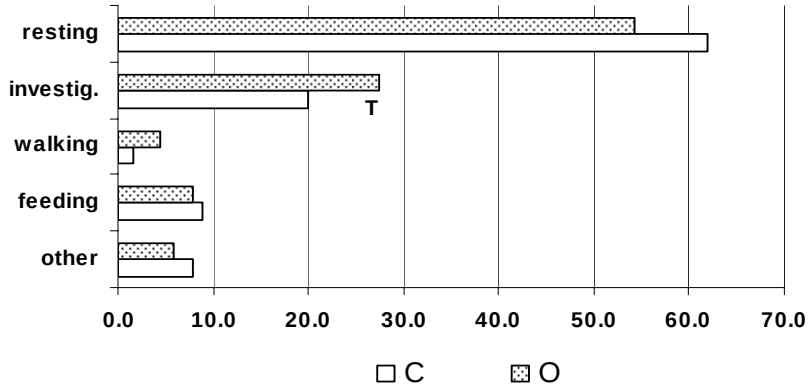

Figure 1. Time-budget (%) during daytime (8 am – 4 pm) according to the husbandry method (n=4 groups of 10 pigs/ system) (T : P< 0.10)

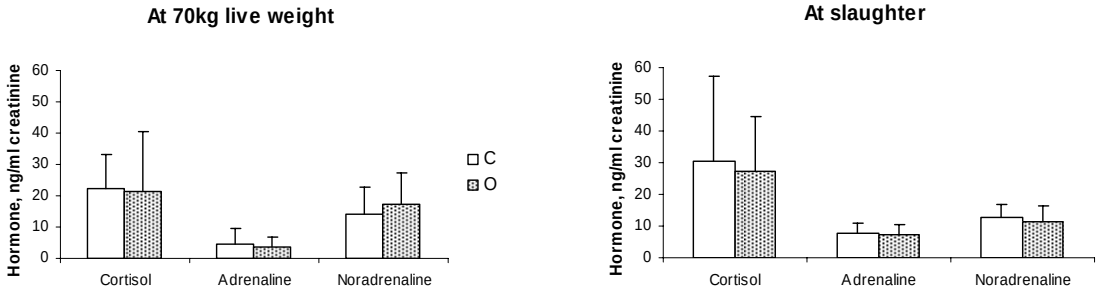

Figure 2. Urine hormone levels during rearing period and at slaughter according to rearing system

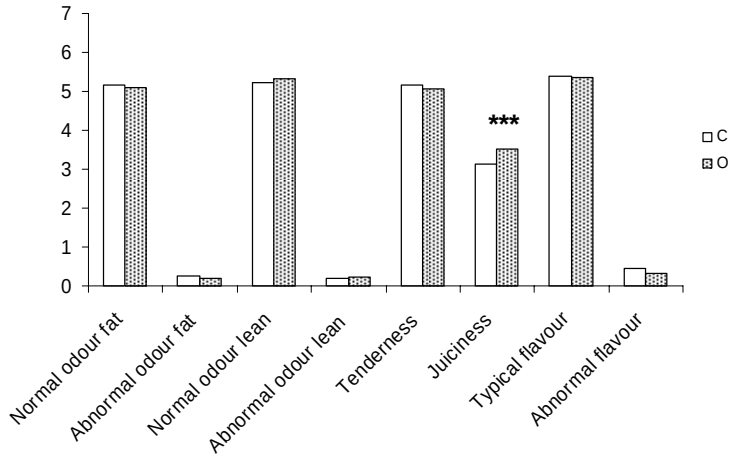

Figure 3. Effects of pig rearing system on meat quality (*** : P<.001)

Table 1. Influence of rearing system on growth performance and carcass traits

	Rearing system[a]		Sign. [b]				
	Outdoor	**Conventional**	**Rsd**	**R**	**G**	**Rep**	**S**
Growth performance							
Initial live weight, kg	35.3	35.1	2.6	ns	ns	***	*
Final live weight, kg	117.7	112.4	6.1	***	ns	**	ns
Feed intake, kg/d	2.91	2.65	0.08	**	-	ns	-
Growth rate, g/d	1003	942	83	**	ns	**	**
Feed conversion, kg/kg	2.80	2.83	0.11	ns	-	ns	-
Slaughter							
Age, d	158.7	158.7	6.2	ns	ns	ns	*
Live weight, kg	115.3	110.1	6.0	***	ns	*	ns
Carcass traits							
Hot carcass weight, kg	93.2	89.6	4.9	**	ns	*	ns
Dressing, %	80.9	81.3	1.4	ns	t	ns	ns
Mean back fat depth, mm	21.0	20.0	2.8	ns	ns	ns	*
Muscle depth, mm	62.6	63.2	5.7	ns	ns	t	ns
Lean meat content (FOM)	59.1	59.8	2.3	ns	ns	ns	**
Internal fat, kg	1.41	1.48	0.3	ns	ns	t	**
Carcass drip loss, %	2.7	2.7	0.2	ns	ns	***	t
Carcass composition, %							
Ham	24.0	24.1	0.6	ns	***	ns	ns
Loin	26.8	26.8	1.4	ns	ns	***	**
Shoulder	24.7	24.8	0.7	ns	ns	*	*
Belly	13.6	14.4	2.8	ns	ns	**	ns
Backfat	7.8	7.5	1.0	ns	*	**	***

[a] n=39 per rearing system for growth performance and carcass traits. n=4 per husbandry method (pens) for feed intake and feed conversion ratio

[b] Statistical significance of rearing system (R), genotype (G), replicate (Rep) and Sex (S); *** : P<0.001 ; ** : P<0.01; * : P<0.05 ; t : P<0.10; ns : P>0.10. Rsd : Residual standard deviation.

Table 2. Influence of rearing system on blood parameters and meat quality traits

	Rearing system [a]		Sign. [b]				
	Outdoor	**Conventional**	**Rsd**	**R**	**G**	**Rep**	**S**
Plasma ACTH, pg/ml	126.5	120.8	108	ns	*	t	ns
Plasma cortisol, ng/ml	59.7	63.1	26.7	ns	ns	ns	ns
***Longissimus* muscle**							
pH_1	6.39	6.42	0.17	ns	ns	**	ns
pH_u	5.57	5.56	0.11	ns	ns	***	ns
Colour							
L*	55.6	54.5	2.9	t	ns	ns	ns
a*	6.6	6.4	1.4	ns	ns	ns	ns
b*	5.5	4.9	0.9	**	ns	ns	ns
Drip losses, %							
2 days post mortem	3.8	2.3	1.7	***	ns	ns	ns
4 days post mortem	6.6	4.6	2.1	***	ns	ns	ns
Intramuscular fat content, %	2.10	1.73	0.4	***	***	*	*
***Biceps femoris* muscle**							
pH_1	6.39	6.45	0.21	ns	ns	t	ns
pH_u	5.58	5.59	0.10	ns	ns	***	ns
Colour							
L*	52.2	51.1	2.8	t	ns	ns	ns
a*	11.2	10.5	1.7	*	ns	ns	ns
b*	6.3	5.8	1.1	*	*	***	ns
Intramuscular fat content, %	2.55	2.14	0.6	**	***	ns	***
***Semimembranosus* muscle**							
pH_1	6.40	6.49	0.21	*	ns	**	ns
pH_u	5.60	5.61	0.11	ns	ns	***	ns
Colour							
L*	53.1	52.3	2.8	ns	ns	ns	ns
a*	10.3	8.9	1.5	***	ns	ns	ns
b*	6.5	5.6	1.0	***	ns	***	t
Intramuscular fat content, %	2.27	1.91	0.5	**	**	*	*

[a] n=39 per rearing system

[b] Statistical significance of rearing system (R), genotype (G), replicate (Rep) and Sex (S); *** : P<0.001 ; ** : P<0.01; * : P<0.05 ; t : P<0.10; ns : P>0.10. Rsd : Residual standard deviation.