LARGE WHITE AND DUROC HEAVYWEIGHT CROSSBRED PIGS: INTERACTIVE EFFECTS OF GENETIC TYPE, REARING AND SLAUGHTER CONDITIONS ON STRESS REACTIVITY AND TECHNOLOGICAL AND SENSORY MEAT QUALITY ASPECTS

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Background

There is an increasing demand for alternatively produced pork. Outdoors produced pork has a good image. However, the effect of rearing environment on technological meat quality varies across studies. To our knowledge, no study reports an improvement in meat quality from outdoor pigs. Use of other genetic types of pigs might improve gustatory acceptability of outdoor produced pork. Increased slaughter weight may increase the effects of rearing environment. As stress at slaughter may reduce or cancel potentially improved pork quality, it is necessary to determine effects of genetic background and rearing environment on reactivity to potentially stressful situations, including slaughter.

Objectives

To study 1) interactive effects of genetic background and rearing environment on stress reactivity and 2) interactive effects of genetic background, rearing environment and slaughter conditions on technological and sensory quality of pork slaughtered at 150 kg live weight.

Materials and methods

Twenty-five Large White (LW) and 52 Duroc (D) crossbreds (barrows and females) were reared indoors (slatted floor, 6.3 m^2) or outdoors (850 m^2 fields with huts) over two consecutive years (April-October), in an unequally balanced design. To study cardiac reactivity, each individual has been subjected to a 5 h isolation test at about 70 kg. In order to obtain similar pre-slaughter and carcass weights, in contrast to outdoor pigs, indoor pigs have been slightly food restricted. At 150 kg, half of the pigs were mixed for 1.5 h and transported for 30 min to the abattoir on the day before slaughter. The other half was unmixed, and slaughtered immediately upon arrival. All pigs had been food deprived for 22 h before slaughter. After bleeding, temperature (15 and 45 min and 24 h), glycogen and lactate content and pH (45 min, 24 h), colour (days 1, 4, 8) and drip (days 3 and 5) were measured on the Longissimus lumborum (LL), the Semispinalis capitis (SC) and the Semimembranosus (SM). Glycolytic potential ([lactate]+2x[glycogen]; GP) was calculated for samples obtained 45 minutes post-bleeding as it reflects muscle glycogen content at the moment of slaughter (Monin and Sellier, 1985). Sensory analysis was performed on half of the loins and on a quarter of the hams, after dry curing, by 12 and 8 trained pannellists, respectively. Data were analysed with analysis of (co-)variance and with pooled Pearson correlations which take into account the means of each treatment group, rather than the overall means. Only main significant effects are reported.

Results and discussion

All pigs showed a similar initial heart rate acceleration following start of isolation, but outdoor pigs showed subsequently a faster decrease ($p<0.01$). Thus, rearing environment influenced cardiac reactivity.

Compared to the no mixing/no lairage group, pigs of the mixing/lairage group had generally lower glycogen levels for the three muscles (Table 1). Compared to indoor pigs, outdoor pigs had generally higher glycogen content for the three muscles. GP of the SM and SC of outdoors pigs was also higher. Effects on glycogen content were partly due to a rearing and slaughter conditions interaction as indoor reared pigs of the mixing/lairage group had lower glycogen content (LL: 24 h, Table 3; SC: 45 min, $p<0.05$ and SM: 45 min, $p=0.06$) than the other three groups. Ultimate pH of the LL and SC reflected main differences in glycogen (Table 2). Lactate content at 24 h was negatively correlated with ultimate pH for the SM ($r=-0.30$; $p<0.01$) and LL ($r=-0.45$; $p<0.0001$) muscles. A slaughter treatment effect was found for lactate content (24

h) of the LL (Table 1). Absence of differences in lactate content (24 h) in the SC despite variations in ultimate pH may be explained by the overall lower lactate production in this muscle, due to its lower glycogen content (Bendall, 1973). Despite their effects on pre-slaughter glycogen content, genetic and rearing background did not influence pH values of the SM. Correlations between pre-slaughter glycogen (glycolytic potential, 45 min) and ultimate pH were stronger for the LL (Pearson, pooled over two years and over LW and D: ($r=-0.42$; $p=0.0001$) and SC ($r=-0.53$; $p<0.00001$) than for the SM ($r=-0.30$; $p<0.01$) suggesting that compared to the SC and LL, ultimate pH of the SM was more strongly influenced by other factors.

The effect of gender depended on genetic type and rearing conditions: female LW had a higher LL glycogen content (Table 3) while outdoor reared barrows had a higher SM glycogen content (24 h; 16.3 ± 1.6 µmol/g) than indoor reared barrows (7.9 ± 1.3 µmol/g; $p<0.01$).

The effect of year depended on the parameter and muscle: for example, the first year, higher levels were obtained for GP of the LL ($p<0.001$), while the SC had lower glycogen content (45 min, 24 h; $p<0.0001$) and GP ($p<0.05$). Ultimate pH did not vary between years, but the first year, at 45 min pH of the LL was higher ($p<0.01$) and of the SM was lower ($p<0.05$). Colour was strongly influenced by slaughter, and to a lesser extent by rearing conditions. LL and SM meat produced by the mixing/lairage group showed overall lower b* and L* values (p varying between 0.06 and 0.0001). Lower a* and b* values ($p<0.05$) of this group of the SC muscle were partly due to the LW of the lairage/mixing group that had significantly lower a* (day 4; $p<0.02$) and b* values (days 4 and 8; $p<0.01$) than the other three groups. Outdoor reared pigs produced meat with higher a* (SM, LL; $p<0.01$) and b* values (LL; $p<0.01$).

In contrast to objective colour data, dry-cured hams of the mixing/lairage group were perceived as redder and in addition, with a higher overall intensity of taste (Table 4). Their loins were also perceived as pinker ($p<0.08$), with a higher colour intensity ($p<0.07$). Dry-cured hams from outdoor produced and D pigs had higher marbling scores and were perceived as fattier. Their hams were overall better appreciated: easier to chew, more tender, less dry although pastier. D hams were found less smoky, while outdoor reared pigs gave softer meat, with more piquant and a longer persistence of taste. Loins from D were also more marbled ($p<0.001$) and had less intense colour ($p<0.05$), pig odour ($p<0.05$) and abnormal taste ($p<0.05$). Outdoor produced pigs gave loins with a stronger grilled aspect ($p<0.03$) which was probably due to an increased Maillard reaction due to their lower humid aspect ($p<0.06$; Bejerholm and Aaslyng, 2003) as these two aspects were negatively correlated ($p<0.02$). Loins from barrows were described as more marbled ($p<0.01$) and with more intramuscular fat ($p<0.001$). Their hams were more also marbled ($p<0.05$) and had a thicker fat layer than females ($p<0.01$), were drier ($p<0.05$) and had a saltier taste ($p<0.05$). Interactions between gender and crossbreed showed that hams from female D had less rancid and spicy odour, and less acid, piquant and spicy taste than the other three groups ($p<0.05$). D barrows produced hams with a peppery taste ($p<0.05$).

Technological and sensory meat quality aspects were not correlated with cardiac stress reactivity measured during rearing, suggesting that rearing or genetic effects are not explained by differences in cardiac reactivity to the slaughter procedure.

Conclusions

Overall, data show that in heavy pigs, meat from an outdoor production or a Duroc genetic background is better appreciated, especially dry-cured ham. Present data show no synergism between outdoor production and Duroc genetic background. The increased appreciation may be related to increased fat content of outdoor or Duroc types of pigs which would also support the advantage of using heavier pigs for high quality dry-cured ham production. However, although fatter than females, castrated males of the Duroc cross were slightly less appreciated, probably due to hormonal differences. Despite large effects of year of experimentation, reported effects of outdoor rearing, genetic type and slaughter conditions were consistent.

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References

Bendall, J.R. 1973. Post mortem changes in muscle. In: Structure and function of Muscle. G.H. Bourne, ed. Academic Press, New York.
Bejerholm, C and M.D. Aaslyng, 2003 The influence of cooking technique and core temperature on results of a sensory analysis of pork - depending on the raw meat quality. Food Qual. Pref., 15: 19-30.
Monin, G. and P. Sellier. 1985. Pork of low technological quality with a normal rate of muscle pH fall in the immediate post-mortem period: The case of the Hampshire breed. Meat Sci. 13: 49-63.

Tables

Table 1a. Main effects of slaughter conditions, housing system and genetic type on glycogen and lactate content of the LL muscle

		Slaughter conditions mixing/lairage no mix/no lair. *F(1,54); p*	housing system in out *F(1,54); p*	genetic type LW D *F(1,54); p*
lactate	24 h	63.79 ± 2.24 **71.55** ± 1.86 *9.18; 0.004*		
glycogen	45 min	36.60 ± 1.91 **43.19** ± 2.00 *4.18; 0.04*		**43.76** ± 2.70 37.93 ± 1.60 *3.11; 0.08*
glycogen	24 h	8.89 ± 0.81 **12.89** ± 0.70 *15.57; 0.0002*	9.41 ± 0.88 **12.44** ± .067 *13.34; 0.0006*	**13.70** ± 1.05 9.46 ± 0.61 *19.51; 0.0001*
GP	45 min	110.4 ± 4.0 **125.8** ± 3.2 *8.74; 0.005*		**131.0** ± 4.96 111.5 ± 2.79 *9.7; 0.0003*

Table 1b. Main effects of slaughter conditions and housing system on glycogen and lactate content of the SC muscle. No effects of genetic type were found.

		Slaughter conditions			housing system		
		mixing/lairage	no mix/no lair	*F(1,54); p*	in	out	*F(1,54); p*
lactate	45 min				**27.90** ± 1.31	23.60 ± 1.37	*15.06; 0.0003*
glycogen	45 min	17.53 ± 2.13	**24.72** ± 1.93	*3.70; 0.06*	15.93 ± 1.44	**26.57** ± 2.35	*15.26; 0.000*
glycogen	24 h				3.30 ± 0.67	**15.72** ± 2.18	*17.16; 0.0001*
GP	45 min	59.78 ± 4.11	**76.32** ± 3.38	*4.70; 0.03*	59.75 ± 3.13	**76.74** ± 4.31	*6.58; 0.01*

Table 1c. Main effects of slaughter conditions, housing system, and genetic type on glycogen and lactate content of the SM muscle

		Slaughter conditions mixing/lairage no mix/no lair. *F(1,54); p*	housing system in out *F(1,54); p*	genetic type LW D *F(1,54); p*
glycogen	45 min	39.66 ± 1.85 **44.88** ± 1.64 *3.04; 0.08*	39.05 ± 1.63 **45.64** ± 1.81 *7.38; 0.009*	**45.99** ± 2.54 40.38 ± 1.35 *4.26; 0.04*
glycogen	24 h	9.87 ± 1.06 **14.46** ± 1.04 *11.78; 0.001*	9.64 ± 0.97 **14.69** ± 1.05 *11.81; 0.001*	**15.82** ± 1.60 10.33 ± 0.70 *12.24; 0.001*
GP	45 min	109.0 ± 3.3 **120.0** ± 2.7 *4.22; 0.04*	108.9 ± 3.2 **120.3** ± 2.8 *6.59; 0.01*	**122.6** ± 4.2 110.4 ± 2.38 *4.11; 0.05*

Table 2. Main effects of slaughter conditions, housing system and genetic type on temperature, pH and drip loss of the LL, SC and SM muscles

			slaughter mixing/lairage	no mix/no lairage	housing system in	out	genetic type LW	D
			F(1,54); p		*F(1,54); p*		*F(1,54); p*	
pH	LL	24 h	**5.59** ± 0.03	5.49 ± 0.01	**5.58** ± 0.03	5.50 ± 0.02		
			8.65; 0.005		*3.65; 0.06*			
drip3	LL	3 days					**5.24** ± 0.40	4.16 ± 0.26
							4.72; 0.03	
T	SC	45 min					**37.2** ± 0.5	35.5 ± 0.6
							3.55; 0.07	
pH	SC	45 min	**6.58** ± 0.02	6.51 ± 0.02				
			7.23; 0.01					
pH	SC	24 h	**5.97** ± 0.05	5.85 ± 0.02	**6.00** ± 0.04	5.82 ± 0.03		
			6.15; 0.02		*6.05; 0.02*			
T	SM	15 min	**40.2** ± 0.1	39.5 ± 0.2	**40.1** ± 0.12	39.6 ± 0.2		
			12.12; 0.001		*9.65; 0.001*			

Table 3. Interactive effects of slaughter conditions, housing system, genetic type and gender on glycogen of the LL muscle

	slaughter * housing				genetic type * gender			
	mixing/lairage		no mixing/no lairage		LW		D	
	in	out	in	out	CM	F	CM	F
	F(1,54); p				*F(1,54); p*			
Glycogen (45 min)					37.4^{a} ± 3.7	49.7^{b} ± 3.4	38.4^{a} ± 2.3	37.4^{a} ± 2.3
					4.62; 0.04			
Glycogen (24 h)	6.4^{a} ± 1.0	11.5^{b} ± 1.2	12.4^{b} ± 1.1	13.4^{b} ± 0.8	11.4^{a} ± 1.3	15.8^{b} ± 1.5	9.5^{a} ± 1.0	9.4^{a} ± 0.7
	10.82; 0.002				*7.73; 0.007*			

	housing * genetic type				
	LW		D		
	in	out	in	out	*F(1,54); p*
Lactate (24 h)	75.60^{a} ± 2.78	$67.07^{a,b}$ ± 4.42	61.22^{b} ± 2.99	70.41^{a} ± 1.69	*16.35; 0.0002*

Table 4. Significant main treatment effects on sensory analysis of dry-cured ham.

	slaughter conditions			housing system			genetic type		
	mix/lairage	no mix./no lair.	*F(1,8); p*	indoors	outdoors	*F(1,8); p*	LW	D	*F(1,8); p*
appearance									
fat betw. muscles							1.10 ± 0.11	**1.42** ± 0.10	*7.92; 0.02*
redness	**3.95** ± 0.15	3.45 ± 0.15	*5.55; 0.05*						
marbling				1.94 ± 0.28	**2.65** ± 0.24	*4.71; 0.06*	1.72 ± 0.18	**2.87** ± 0.26	*19.3; 0.007*
hardness				**1.24** ± 0.13	0.89 ± 0.09	*5.16; 0.05*			
uneven colour	2.10 ± 0.14	**2.83** ± 0.17	*7.86; 0.02*						
texture									
easy to chew				3.57 ± 0.08	**4.05** ± 0.11	*10.65; 0.01*	3.65 ± 0.11	**3.98** ± 0.12	*7.34; 0.03*
tender				3.21 ± 0.10	**3.66** ± 0.16	*5.89; 0.04*	3.21 ± 0.13	**3.66** ± 0.13	*7.30; 0.03*
pasty				0.75 ± 0.16	**1.29** ± 0.21	*4.98; 0.06*	0.64 ± 0.15	**1.41** ± 0.18	*11.9; 0.009*
dry				**3.06** ± 0.11	2.40 ± 0.16	*20.6; 0.002*	**3.01** ± 0.11	2.46 ± 0.17	*20.5; 0.002*
fatty	1.14 ± 0.14	**1.46** ± 0.12	*5.55; 0.05*	1.08 ± 0.10	**1.51** ± 0.14	*8.50; 0.02*	1.17 ± 0.11	**1.41** ± 0.15	*6.65; 0.03*
taste									
overall intensity	**4.20** ± 0.05	3.92 ± 0.08	*5.97; 0.04*	3.97 ± 0.07	**4.15** ± 0.08	*5.18; 0.05*			
smoky							**0.12** ± 0.03	0.03 ± 0.02	*6.23; 0.04*
piquant				0.77 ± 0.09	**0.96** ± 0.13	*5.02; 0.06*			
persistence				3.10 ± 0.07	**3.40** ± 0.09	*6.26; 0.04*			