EFFECTS OF VARIOUS PRESLAUGHTER HANDLING TREATMENTS ON THE COLOUR OF DIFFERENT PORK MUSCLES

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Background

Colour is one of the most important quality attributes of pork because colour can be easily assessed by both producers and consumers. In addition, colour is related to other important quality aspects. Various phases during preslaughter handling, such as transport (Leheska et al., 2003), lairage (Pérez et al., 2002) and stress immediately before slaughter (Hambrecht et al., 2004b) may affect pork colour. Due to its size and accessibility, the LM is the most frequently assessed muscle. However, muscles consist of various fibre types that determine the metabolic properties of a muscle. It can be expected that muscles, depending on their anatomical location and metabolic profile, react differently to the physical and psychological stressors associated with preslaughter handling. In agreement, Warner et al. (1993) found that the longissimus, a predominantly glycolytic muscle, was a reliable pork quality indicator for other muscles when its colour was dark and exudate low. However, when its colour was pale and exudate high, quality of the longissimus muscle was only related to the major ham muscles and not to the shoulder muscles that have a more oxidative metabolism.

Objectives

The objective of the present experiment was to investigate whether the effects of transport, lairage, and preslaughter stress on colour are different in various, commercially important pork muscles.

Materials and methods

All pigs were commercial halothane-free end products of the *Hypor* pig breeding company. Pigs (n= 384) were assigned to one of eight treatments in a 2 × 2 × 2 factorial arrangement, with two types of transport (short (50 min) and smooth or long (3 h) and rough), two lairage durations (long (3 h; considered as optimal) or short (<45 min; considered as sub-optimal)) and two stress levels immediately before slaughter (minimal or high). Eight groups of 48 pigs, all originating from the same commercial farm, were processed during eight weeks on various days. Long and short lairage alternated between consecutive weeks. Transport types and preslaughter stress levels were varied within the same slaughter day. Pigs were electrically stunned in a fully automated, head-to-heart stunning system at a commercial plant. At 23 h post-mortem pork cuts were harvested for colour measurements. All measurements were done after a 10-min blooming period with a Minolta Portable Chroma Meter (Model CR 210). L* (lightness), a* (redness), and b* (yellowness) values were assessed in the *longissimus lumborum* muscle (**LL**) at the level of the third lumbar vertebra, in the *longissimus thoracic* muscle (**LT**) at the level of the 6th thoracic vertebra, in the *serratus ventralis* muscle (**SV**), and in the *semimembranosus* muscle (**SM**). Data were analysed by the mixed-model procedure (PROC MIXED) of SAS. Tests of multiple comparisons of least squares means were adjusted according to the TUKEY-KRAMER method to ensure the overall significance level of $P = 0.05$. The model applied included the fixed effects of muscle type, transport conditions, lairage duration, and stressor level, as well as their 2-way interactions, and the random effect of slaughter day nested within lairage.

Results and discussion

Effects of transport

Results are presented in Table 1. Long and rough compared with short and smooth transport decreased ($P < 0.05$) the yellowness of the meat. No other main effects or interactions between the transport treatment and muscle type were observed. The meat was darker (i.e. lower L* values) when transport was long and rough and pigs were additionally subjected to the short lairage treatment (transport × lairage interaction; $P < 0.05$; results not shown). This effect was similar for all muscles but the largest effect was observed in the SV muscle. Transport had no effect on the redness in the minimal preslaughter stress group. In the high stress group, however, long as opposed to short transport increased the redness in the LT and SM muscles but decreased the redness in the SV muscle (*P* < 0.05; results not shown). LL redness was not affected (*P* > 0.05). These effects on redness are probably related to differences in the relative proportions of the various myoglobin forms (Lindahl et al., 2001) but remain difficult to explain. The physical exercise and psychological stress that is associated with transport varies depending on the type of transport. Transport in general was shown to be stressful for pigs (Geverink et al., 1998) and even more so in rough as opposed to smooth transports (Bradshaw et al., 1996). As a consequence, both the physical exercise and the psychological stress level was probably higher in the long and rough compared with the short and smooth transport treatment. Oxidative muscle fibres are preferentially recruited at low intensity exercise levels (Køpke et al., 1984; Lacourt and Tarrant, 1985) and were shown to be more sensitive to adrenaline (Górski, 1978; Fernandez et al., 1995) which is secreted in response to psychological stress. Consequently, it was expected that the SV, a more oxidative muscle compared with the other muscles, would show a larger response. This was only partly true, which is probably related to the small differences in exercise and stress level between the two transport treatments.

Effects of lairage

For the lairage treatments there was for all colour values an interaction between lairage and muscle type noted (*P* < 0.05). For the L* value, this was probably due to the relatively large decrease (*P* < 0.05) in lightness in the SV muscle, whereas the response to the short lairage duration was small in the LT and intermediate in the SM and LL muscles (*P* > 0.05). Regarding the a* value, the SV was again the only muscle that showed a difference (*P* < 0.05) between long and short lairage with a decreased redness after a short lairage period. None of the pair wise comparisons were significant for the b* values, but both the LL, SM and SV muscles appeared to exhibit a, numerically, lower yellowness for the short lairage treatment whereas there was no difference in b* values noted for the LT. Lairage is not a stress factor itself but is meant to provide a rest for pigs to recover from previous transport stress. Lairage times shorter than 45 min are usually considered as too short for recovery (Milligan et al., 1998; Pérez et al., 2002) whereas 3 h is often regarded as optimal for pigs (Warriss et al. 1998; Pérez et al., 2002). In agreement with the above mentioned higher adrenaline sensitivity and recruitment at low exercise intensity of oxidative muscle fibres, the oxidative SV muscle showed a somewhat larger response to the short lairage treatment. Another reason may be the heavier involvement of the shoulder and neck muscles in activities such as posture holding during transport, exploring and fighting due to mixing of foreign pigs and, as a consequence, an increased need for rest compared with other muscles.

Effects of stress

For all colour values, there were interactions between the stressor treatment and muscle (*P* < 0.001). High stress compared with minimal stress resulted in paler meat in the LT (*P* < 0.05) whereas the SV muscle became darker in response to high stress (*P* > 0.05). Meat was less red (*P* < 0.05) in both the LT and the SV for the high stressor treatment while SM redness seemed to be increased (*P* > 0.05). Whereas LL lightness and redness appeared to be hardly affected by preslaughter stress, the yellowness of the LL was, similar to SV yellowness, decreased (*P* < 0.05). No effect on yellowness was seen in the SM but LT yellowness was increased (*P* < 0.05) in response to high stress. The high stressor treatment was previously tested and shown to be associated with a high level of both physical exercise and psychological stress as well as large effects on pork quality (Hambrecht et al. 2004a,b). In agreement with the previously mentioned differences in adrenaline sensitivity, response to exercise intensity and involvement in physical activity, effects of the stressor treatment depended on muscle type. Barton-Gade and Olsen (1987) compared stress-susceptible pigs with stress-resistant pigs and found an increased incidence of PSE in glycolytic muscles such as the LM whereas oxidative muscles, including the SV, showed an increased incidence of the DFD condition. These results are supported by the effects of the high stressor treatment in the present experiment. Additionally, the present study shows that considerable variation exists for pork colour measured within the longissimus muscle. The high stressor treatment produced different and larger effects in the LT compared with the LL muscle. The reasons for these differences within the longissimus muscle are unknown. But results are in agreement with Lundström and Malmfors (1985) who showed a higher incidence of PSE in the shoulder part of the loin, compared with the mid-loin and the ham site of the loin.

Conclusions

Effects of preslaughter treatments depend on the muscle that is studied. The metabolic profile but also the location of a muscle play a crucial role. High stress levels associated with preslaughter handling may promote PSE development in some glycolytic muscles whereas more oxidative muscles will rather develop DFD pork. Effects of preslaughter handling on pork quality should be assessed not only in one but in several muscles.

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Table 1. Effect of transport, lairage, and preslaughter stress on pork colour in the longissimus lumborum (LL), the longissimus thoracic (LT), the semimembranosus (SM), and the serratus ventralis (SV) muscles[a]

		L* value		a* value		b* value	
Transport × muscle		Short transport (n=174)	Long transport (n=184)	Short transport (n=174)	Long transport (n=184)	Short transport (n=174)	Long transport (n=184)
	LL	53.9	53.7	19.4	19.1	5.5	5.3
	LT	58.9	59.1	19.2	19.2	5.6	5.6
	SM	54.4	54.0	19.7	19.9	6.5	6.5
	SV	38.9	38.5	24.3	24.1	4.3	4.1
	Pooled SE	0.23	0.23	0.09	0.09	0.10	0.10
Lairage × muscle		Long lairage (n=179)	Short lairage (n=179)	Long lairage (n=179)	Short lairage (n=179)	Long lairage (n=179)	Short lairage (n=179)
	LL	54.4	53.0	19.4	19.1	5.5	5.2
	LT	59.2	58.9	19.3	19.1	5.6	5.6
	SM	54.5	53.6	19.6	19.9	6.7	6.3
	SV	39.4^{y}	37.7^{x}	24.5^{y}	23.9^{x}	4.3	4.0
	Pooled SE	0.25	0.25	0.09	0.09	0.12	0.12
Stress × muscle		Minimal stress (n=177)	High stress (n=181)	Minimal stress (n=177)	High stress (n=181)	Minimal stress (n=177)	High stress (n=181)
	LL	53.9	53.7	19.2	19.3	5.5^{y}	5.2^{x}
	LT	57.1^{x}	60.8^{y}	19.5^{y}	18.9^{x}	5.3^{y}	5.9^{x}
	SM	54.2	54.2	19.6	20.0	6.5	6.5
	SV	39.1	38.3	24.5^{y}	23.9^{x}	4.4^{y}	4.0^{x}
	Pooled SE	0.23	0.23	0.09	0.09	0.10	0.10
P-values	Transport (T)	0.206		0.157		**0.010**	
	Lairage (L)	**0.024**		**0.061**		0.110	
	Stress (S)	**0.001**		**0.002**		0.303	
	Muscle (M)	**0.001**		**0.001**		**0.001**	
	T × M	0.509		0.102		0.589	
	L × M	**0.009**		**0.001**		**0.016**	
	S × M	**0.001**		**0.001**		**0.001**	
	T × L	**0.020**		0.547		0.491	
	T × S	0.411		**0.003**		0.426	
	L × S	0.524		0.736		0.127	

[xy]Least squares means within muscle, 2-way interaction and colour attribute lacking a common superscript letter differ ($P < 0.05$).