EFFECT OF TRANSPORT, LAIRAGE, AND PRESLAUGHTER STRESS ON PORK MEAT QUALITY

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Background

Preslaughter handling of pigs, including stockman interaction (loading, unloading, driving animals), transport, and lairage, has been designed to meet the pork industry's requirements rather than the pig's needs. Various preslaughter handling such as transport (Warris and Bevis, 1986), lairage (Brown et al, 1999), and preslaughter stress (Hambrecht et al., 2004a) can trigger a stress response and may have negative consequences for pork quality aspects such as color, water-holding capacity, and other sensory characteristics. Warris (1998) and Gispert et al. (2000) found that pigs transported for long periods of time are more likely to form dark-firm-dry pork because of exhaustion and fatigue. Bradshaw et al. (1996) found that short (≤1h) compared with long transports were more detrimental because the pigs did not recover from the stress of loading and could not adapt to the conditions of transport. The effect of lairage duration depends on factors such as environmental temperature and mixing. Aaslyng and Gade (2001) found that a lairage time of less than one hour does not allow for sufficient resting and may negatively impact both animal welfare and meat quality. However, extended lairage times of six hours and more may increase carcass damage and stress caused by fighting and prolonged periods without feed (Warriss, 1998). The negative factors associated with transport, lairage, and preslaughter stress increase the chances of economic losses to producers and packers.

Objectives

The objective of this experiment was to investigate to what extent various important preslaughter handling factors such as transport conditions, lairage duration and stress level immediately before slaughter affect muscle energy, blood-based stress indicators, and ultimate pork quality.

Materials and methods

All pigs were commercial halothane-free progeny of the Hypor pig breeding company. Pigs (n = 384) were assigned to one of eight treatments in a 2 x 2 x 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 administered immediately before slaughter (minimal or high). Pigs were penned 12 pigs per pen at the production site. For each treatment, groups of four random pigs were removed (four pigs taken from each of 3 pens to form groups of 12) from their home pens on the production site and randomly allocated to either minimal or high preslaughter stress and either short and smooth or long and rough transport. Long and short lairage alternated between consecutive weeks. Transport duration and preslaugher stress levels were varied within the same slaughter day. Eight groups of 48 pigs were processed over a series of weeks at a commercial plant. Pigs were electrically stunned in a fully automated, head-to-heart stunning system. Blood samples were collected in a heparinized tube at exanguination for cortisol and lactate determination. A 1-g muscle sample was taken at 135 min postmortem from the longissimus muscle (LM) at the last rib and frozen in liquid nitrogen for determination of the glycolitic potential, a good approximation of in vivo muscle glycogen. At 30 min, 3 h and 24 h postmortem temperature and pH were measured in the LM adjacent to the third lumbar vertebra**.** At 23 h postmortem loins were harvested for final meat quality measurements. L* (lightness), a* (redness), and b*(yellowness) color values were assessed in the LM on a freshly cut surface after a 10 minute blooming period with a Minolta Portable Chroma Meter (Model CR 210**).** Electical conductivity was measured using the LF-Star. Water-holding capacity was measured by pressing a filter paper on a freshly cut surface and measuring the amount of absorbed moisture after 10 sec. Additionally, drip loss was determined as percentage of weight lost from a LM slice after 1, 3, and 7 d of storage lying face down on a metal grid in a closed plastic container. Data were analyzed 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 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

Stress indicators in blood

Results are presented in Table 1 and 2. High preslaughter stress increased ($P < 0.05$) plasma lactate and cortisol concentrations. The increase in plasma lactate concentrations seemed to be larger after both long vs. short transport (transport x stress interaction; $P < 0.05$) and after the short vs. long lairage (lairage x stress interaction; $P < 0.05$). Cortisol levels were increased after short transport only when followed by short lairage (transport x lairage interaction; $P < 0.05$). Lairage is meant to serve as a period of recovery for animals after transport. The larger increases in plasma cortisol and lactate in response to high stress indicate that both the long transport and the short lairage treatment were unfavorable and made the pigs more susceptible to subsequent stress. Moreover, the increase in cortisol concentration after short transport in combination with short lairage was probably due to a lack of recovery time in lairage from the stressful experience of loading, transport, and unloading. Results of the present expirement are in agreement with studies that showed that rough vs. smooth transport (Bradshaw et al., 1996), short vs. long lairage (Perez et al., 2002) and high vs. minimal stress (Hambrecht et al., 2004a) caused stress in pigs as indicated by elevated blood-based stress indicators.

Muscle glycolitic potential and pork quality

Long transport increased ($P < 0.05$) LM glycolitic potential with a concomitantly increased muscle lactate production. This is in disagreement with Leheska et al. (2003) who found a significant muscle energy depletion in response to longer transports and indicates that the transport treatment in the present study was physically not exhausting. Lairage had no effect on muscle energy stores whereas high preslaughter stress increased ($P < 0.05$) LM lactate production but overall decreased ($P < 0.05$) muscle glycolitic potential and muscle glycogen.

Transport and lairage did not affect pH at 30 min postmortem. At 3 h postmortem, the slightly decreased muscle glycogen and glycolitic potential after short compared with long lairage ($P < 0.05$) were reflected in a higher pH. The pH values seemed to be more increased when short lairage was combined with long transport (transport x lairage interaction; $P < 0.05$). Ultimate pH, however, was not affected by transport conditions or lairage duration. Similar to cortisol concentrations, LM temperature at 40 min was increased ($P < 0.05$) for the short transport group only when followed by short lairage. In agreement with the increased rate of lactate production, high stress decreased ($P < 0.05$) muscle pH at 30 min and 3 h postmortem. Corresponding to the lower glycolitic potentials, ultimate pH was increased ($P < 0.05$) in the high stress group. However, ultimate pH was still within the normal range of 5.3 to 5.7 (Briskey, 1964). At 3 h postmortem, high stress resulted in an increased LM temperature, but this increase was larger after long lairage (lairage x stress interaction; $P < 0.05$). This finding is difficult to explain since a similar effect was not found at 40 min postmortem. However, it is possible that long lairage allowed the pigs to relax before stress shock occured, or toward the end of long lairage pigs began to fight (resulting in an increased body temperature) and combined with the high stress, fueled the increased in muscle temperature.

High preslaughter stress increased ($P < 0.05$) filter paper moisture uptake, electrical conductivity and drip loss throughout the entire 7 day storage period. This is in agreement with the elevated muscle temperature and lower pH values that are known to be related to inferior pork quality (Cassens et al., 1963; Bowker et al., 2000). Moreover, other experiments studying the effect of high preslaughter stress on pork quality confirm the detrimental effects of stress on pork quality (van der Wal et al., 1999; Hambrecht et al., 2004a). However, despite the influence of preslaughter stress on postmortem pH, lightness and redness were not affected ($P < 0.05$). Long lairage resulted in an increased ($P < 0.05$) paleness (i.e. high L* values) in loins.

Conclusions

Preslaughter stress exerted the largest influence on animal welfare and ultimate pork quality. Therefore, it is imperative that slaughterhouse employees are educated with regard to proper, low stress animal handling procedures. Furthermore, slaughter plant design should be considered as an important tool in improving pork quality and animal welfare.

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Table 1. Effect of transport (T), lairage (L), and preslaughter stress (S) on stress indicators, muscle metabolites, pH and temperature as well as water-holding capacity and color in the longissimus muscle[a].

	Transport		Lairage		Stress			P-Value		
Item	Short	Long	Long	Short	Min.	High	Pooled SE	T	L	S
No. Animals	174	184	179	179	176	181	-	-	-	-
Blood										
Cortisol, ng/mL	67.5	65.5	61.4	71.7	55.1	77.9	4.28	0.434	0.201	0.001
Lactate, mmol/L	23.8	24.1	24.4	23.5	17.1	30.9	0.61	0.617	0.401	0.001
Muscle/meat										
Glycolitic potential, µmol/g	129.4	132.5	132.2	129.7	134.1	127.8	1.45	0.060	0.304	0.001
Lactate, µmol/g	70.2	74.3	72.0	72.6	58.1	86.4	1.08	0.008	0.736	0.001
Glycogen, µmol/g	29.6	29.1	30.1	28.6	38.0	20.7	0.77	0.621	0.155	0.001
pH										
30 min	6.51	6.46	6.49	6.48	6.64	6.33	0.027	0.079	0.740	0.001

Table 1. Continued

	Transport		Lairage		Stress			P-Value		
Item	Short	Long	Long	Short	Min.	High	Pooled SE	T	L	S
No. Animals	174	184	179	179	176	181	-	-	-	-
pH										
3 h	6.10	6.05	6.01	6.14	6.23	5.92	0.050	0.094	0.202	0.001
24 h (ultimate)	5.55	5.55	5.54	5.57	5.52	5.58	0.019	0.883	0.482	0.001
Temperature										
40 min	39.4	39.1	39.0	39.4	38.6	39.8	0.27	0.039	0.427	0.001
3 h	21.2	21.3	21.2	21.3	20.6	21.9	0.34	0.760	0.967	0.001
Electrical conductivity	8.0	8.5	7.9	8.6	6.3	10.2	0.64	0.083	0.536	0.001
Filter-paper moisture	67	65	67	65	53	80	3.6	0.437	0.727	0.001
Drip loss, %										
Day 1	1.96	2.01	1.89	2.08	1.25	2.73	0.12	0.757	0.331	0.001
Day 3	4.34	4.44	4.27	4.52	3.32	5.46	0.27	0.593	0.598	0.001
Day 7	6.19	6.30	6.01	6.48	5.21	7.27	0.24	0.575	0.277	0.001
L* value	53.9	53.7	54.3	53.3	53.9	53.7	0.23	0.529	0.029	0.494
a* value	19.4	19.1	19.4	19.1	19.2	19.3	0.11	0.008	0.141	0.411
b* value	5.5	5.3	5.5	5.2	5.5	5.2	0.10	0.018	0.100	0.001

[a]Data in the table are presented as least squares means.

Table 2. Significant (P < 0.05) two-way interactions between transport (T), lairage (L), and stress (S) [a].

	Transport × Lairage				Transport × Stress				Lairage × Stress			
	ST[b]		LT[c]		ST[b]		LT[c]		LL[d]		SL[e]	
Blood	LL[d]	SL[e]	LL[d]	SL[e]	MS[f]	HS[g]	MS[f]	HS[g]	MS[f]	HS[g]	MS[f]	HS[g]
Cortisol ng/mL	58.8^{xy}	76.1^{y}	63.9^{xy}	67.2^{x}	-	-	-	-	-	-	-	-
Lactate mmol/mL	-	-	-	-	17.6^{x}	30.1^{y}	16.5^{x}	31.6^{y}	18.4^{x}	30.4^{y}	15.8^{x}	31.3^{y}
pH												
3 hours	6.07^{xy}	6.12^{y}	5.96^{x}	6.15^{y}	-	-	-	-	-	-	-	-
Temp.[h]												
40-min	39.0^{x}	39.7^{y}	39.1^{xy}	39.2^{xy}	-	-	-	-	-	-	-	-
3-h	-	-	-	-	-	-	-	-	20.3^{wx}	22.2^{yz}	20.8^{wy}	21.7^{xz}

[a]Data in the table are presented as least square means
[b]ST = short transport
[c]LT = long transport
[d]LL = long lairage
[e]SL = short lairage
[f]MS = minimal stress
[g]HS = high stress
[h]Temp .= Temperature measured in degrees celcius (Cº)
[wxyz]Least squares means, within a two-way interaction, lacking a common superscript letter differ (P < 0.05).