E EFFECT OF CHILLING, ELECTRICAL STIMULATION AND CONDITIONING ON PORK EATING QUALITY

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e effect of three different post-slaughter treatments and subsequent conditioning times on the eating quality of pork was studied, using a al of 36 boars and 36 gilts (80-90 kg live wt.). The treatments were, (A)- holding in air at >10°C for 3 h, followed by chilling in air at C; (B)- chilling in air at 1° (C; (C)- high voltage electrical stimulation (ES) at 20 min post-slaughter, followed by treatment B. ality attributes were measured in *M.longissimus thoracis et lumborum* (LTL) and in *M. semimembranosus* (Sm).

re was little difference in cooling rate between the three treatments; the major effect on quality came from the use of ES in treatment C. ES uced pH at 45 min by approximately 0.3 units, and achieved pH values at 3h post-slaughter of 5.64 (LTL) and 5.87 (Sm). ES did not duce PSE meat. Drip losses were generally low, but were slightly higher with treatment C. By all three instrumental texture parameters, L from treatment C was significantly more tender than from A and B at 4 d, 7 d and 12 d post-slaughter, suggesting that either some cold-ghening with A and B was overcome by ES in treatment C or that ES had some other action. Conditioning at 1°C improved tenderness of L from 4 d to 7 d and further to 12 d. Taste panelling of loin chops and Sm roast confirmed that treatment C gave significantly more der meat than A and B, and that ageing from 4 d to 7 d and further to 12 d significantly improved tenderness. Treatment C, with ES, duced loin muscle which was more tender at 4 d than at 12 d with the other treatments.

TRODUCTION

spite the faster glycolytic rate in pig muscle, cold-toughening in pork has been reported by several workers (Marsh et al, 1972; Gigiel & es, 1984; Dransfield & Lockyer, 1985; Barton-Gade et al, 1987; Moller & Vestergaard, 1988). In most cases, the toughening has been ociated with rapid chilling procedures. Several studies have shown that electrical stimulation (ES) can improve tenderness of pork, sumably by avoiding cold-toughening. On the other hand, some researchers have found no tenderising effect from ES or even harmful ects such as increased drip loss.

ylor & Tantikov (1989; 1992) and Dransfield et al (1990) have demonstrated a clear improvement in tenderness of pork from applying high tage ES to carcasses at 20 minutes post-slaughter. ES had a tenderising effect not only with rapidly chilled carcasses, but also to some ent with carcasses which had been conventionally chilled at 1°C and were therefore less prone to cold-toughening.

e present study was designed to establish whether the same ES procedure improved tenderness in pig carcasses subjected to conventional ling at 1°C, and to compare the level of tenderness achieved with that obtained with a slower process where chilling was delayed by 3 h.

PERIMENTAL

s. The experimental design required six groups of 12 pigs, each group consisting of 6 entire males and 6 gilts. The pigs were selected e of bacon weight (80-90kg live weight) of white breeding, low incidence of the halothane gene and P_2 between 8-12mm.

illing/ES treatments- The three post-slaughter treatments examined were,

Delay at 10°C until 3 h post-slaughter, and cooling at 1°C; (B) Cooling at 1°C; (C) High voltage ES and cooling at 1°C onditions were: 700v peak, 12.5 Hz, for 90 sec. applied 20 min post-slaughter to whole carcasses. At each slaughter time, 2 males and ilts were subjected to each of the 3 treatments.

t - Fat thickness was measured in the P_2 position on hot carcasses using an intrascope and marbling fat in LTL by the Soxhlet method.

oling rate - Carcasses were split before cooling and temperatures were recorded in deep LTL and deep leg during the 24 h period.

- pH was measured in the LTL at 10/11th rib and the Sm of each carcass at 45 min, 3h and 24h. Measurements were made on 1g scle homogenised in 10ml iodoacetate solution, using a Radiometer pH meter and combined electrode.

our - Lightness of LTL at the last rib was assessed 24h post-slaughter, using CIELAB L* measured on a Minolta Chroma Meter.

scle opacity - The opacity of LTL was measured at 24h post-slaughter using a fibre optic probe (FOP).

p loss - A section of LTL from each carcass adjacent to that used for colour measurement was used for recording drip loss, by pending a 25 mm thick slice of the muscle inside a plastic bag, so that the drip accumulating over three days could be weighed.

trumental texture (Volodkevitch) - A 30 cm section of LTL was removed from one side of each carcass at 24 hours and divided o three portions which were vacuum packed and aged at 1°C for assessment at 4, 7 and 12 d post-slaughter. A portion of Sm was similarly ged to provide a sample at 4 d. The muscle samples were cooked in a water bath at 80°C to a centre temperature of 78°C and cooled rnight. Six blocks (10 x 10 x 20 mm) were cut from each muscle sample, with the longest side parallel to fibre direction, and assessed ng Volodkevitch-type jaws on a Stevens CR Analyser. Three measurements of texture were recorded: force at first yield, compressive e (both in kg) and total work done (J. 10^{-2}).

te panelling - From each carcass, three 10 cm long sections of LTL were removed at 24h post-slaughter, vacuum packed and aged at until 4, 7 and 12 d after slaughter. After ageing, the vacuum packed samples were blast frozen and stored at -20°C until required for assessment, at which time they were defrosted and cut into 25 mm slices. These were cooked on a pre-heated griddle, turning every 3 until centre temperature was 80°C. Slices were cut into 2 x 3 cm blocks and submitted, hot, to 10 panellists.

At each session, assessors received samples of each of the 3 treatments and 2 ageing times which they evaluated on an 8-point scale ranging from "extremely tough" (1) to "extremely tender" (8).

From the same side of each carcass, the Sm was removed at 24h post-slaughter, vacuum packed and aged at 1°C until 4 d post-slaughter. The muscle samples were roasted to an internal temperature of 80°C, and panellists given 1 cm thick slices to evaluate.

Analysis of data - The data were subjected to variance analysis to examine the effect of the post-slaughter treatments. Differences were tested for significance at the 5% level, based on the standard error of the difference between means obtained from the analysis of variance. These differences are indicated in the tables as superscripts and those attached to any mean value represent the treatment(s) which are significantly different from the mean, using treatment identifiers a, b, c.

RESULTS

Carcass characteristics - There was no significant difference between treatments in either carcass weight or in backfat thickness. Marbling fat was, however, slightly higher (1.1%) in carcasses in Treatment A, compared with that in Treatments B & C (0.8%).

Cooling rate - Treatment A reduced deep LTL to 10°C by 6.2h from slaughter, and the deep leg by 9.4h. Corresponding times for Treatments B & C were 5.6h and 9h respectively.

pH - The post-slaughter changes in pH of LTL and Sm are shown in Table 1. At 45 min and 3 h post-slaughter, the pH in the stimulated carcasses (Treatment C) was lower (P<.001) in both LTL and Sm than with the other two treatments. At 24h, pH was slightly, but not significantly, lower in LTL and Sm of stimulated carcasses (Treatment C).

Colour - CIELAB colour coefficient L* (lightness), and fibre optic probe (FOP) values are shown in Table 2. Treatment C, with ES, gave slightly lighter pork (P = .003) than the other two treatments. Muscle opacity values by FOP were also slightly higher with Treatment C. FOP values were generally low, with the highest mean value recorded at 25, well below the level associated with PSE pork (> 50).

Drip loss - Drip losses from LTL and Sm over 72h are shown in Table 2. There was no significant treatment effect in either LTL or Sm, although LTL samples from Treatment C tended to lose more drip than those from the other two treatments.

Instrumental texture (Volodkevitch) - Table 3 shows mean values for three texture parameters, measured in LTL at 4, 7 and 12d after slaughter, and in Sm at 4d. For LTL, Treatment C gave significantly more tender meat, expressed by all three parameters, than treatments A & B, which did not differ significantly. This was true for all ageing times.

1. Yield at first break (Yf) with Treatment C was lower by about 1.5 kg after 4 d (P = 0.001), 7 d (P<0.001) and 12 d (P = 0.002).
2. Compression (Cf) with Treatment C was lower by more than 1.5 kg after 4 d (P = 0.006), 7 d (P<0.001) and 12 d (P = 0.002).
3. Work done (W) with Treatment C was lower by more than 5 $J.10^{-2}$ after 4 d (P = 0.004), 7 d (P = 0.001) and 12 d (P = 0.01).

In addition to the effect of treatment, an improvement in tenderness with ageing was observed by all parameters after 7 and 12 d. Ageing for up to 12 d after Treatments A & B did not achieve the some degree of tenderness as Treatment C within 4 d.

For Sm, measured only at 4 d post-slaughter, there was no significant difference with treatment, although the trend, by all three parameters, was towards more tender samples from Treatment C. Treatment A, where chilling had been delayed, tended to give slightly tougher samples.

Taste-panelling - Taste-panel scores for tenderness of griddled loin slices and roast Sm joints are shown in Table 4.

Mean ratings are shown for tenderness. For LTL there was no interaction between treatment and ageing. The mean values show quite clearly that the most tender samples came from Treatment C. At both 4 and 7 d, Treatment C produced significant (P<0.01) improvements in tenderness, but there was no effect of treatment at 12 d. For Sm, the difference between treatments was significant (P<0.001) with Treatment C giving the most tender meat.

DISCUSSION

Gross carcass characteristics were, with the exception of marbling fat, similar across treatments, so that the effects of the latter on meat quality attributes could be compared. The slightly higher marbling in Treatment A carcasses might have been expected to enhance tenderness. Delaying chilling for 3 h in Treatment A made little difference to the rate of cooling of deep LTL and Sm compared to Treatments B & C. Differences in eating quality can be therefore attributed more confidently to the use of ES in Treatment C.

The principal difference in treatmnet effect was the rapid pH fall induced by ES in Treatment C. By 45 min. pH in stimulated carcasses was approximately 0.3 units lower than in the non-stimulated carcasses; by 3h the difference had increased so that pH in stimulated carcasses was near ultimate levels. The rapid pH fall with ES was the likely cause of the lighter colour of LTL and the higher FOP value with Treatment C, indicating a slight denaturation of the muscle. This increased lightness was, however, only slight and probably invisible to the eye.

Although the general level of drip was low, the slightly higher loss from LTL after Treatment C could also be attributed to ES, but it does suggest the importance of coupling rapid chilling to ES, so that the slight disadvantages associated with rapid pH fall are minimised.

The clearest effect of treatment was on meat tenderness measured instrumentally and by taste-panel. By all measured parameters, Treatment C produced LTL which was significantly more tender than with Treatments A & B, between which there was no difference. The improvement in tenderness was attributed to ES since it was the only effective difference between Treatments C and B. The magnitude of the ovement was such that LTL samples from Treatment C were more tender by 4 d than those from Treatments A & B after 12 d ageing. derness was improved all treatments by ageing from 4 d to 7 d and to 12 d. The improvement in tenderness with ageing wasin addition to other effects of treatments, so that the relatively greater tenderness of LTL after Treatment C was as pronounced after 12 d as it was at . The Sm was less affected by treatment and differences were not significant, although Treatment C samples were measured most tender all three texture parameters.

e instrumental texture results are strongly supported by the taste-panel with significantly higher tenderness ratings for Treatment C mples, not only for LTL but also for Sm where the instrumental difference were not significant. The magnitude of these improvements re equal to, or greater than, the 0.5 improvement in tenderness attributed by Warkup *et al* (1990) to difference in finding regimen. The ect of ageing was also well demonstrated.

NCLUSIONS

ese results suggest that, even under the conventional cooling conditions used in this study, an appreciable amount of cold-shortening urs in pig carcasses and it can be avoided by ES. Delaying chilling by 3 h gave no improvement in tenderness, whereas ageing up to 12 d e an overall improvement, but the greatest improvement in tenderness came from application of high voltage ES at 20 min after slaughter

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le 1. pH at 45 min, 3 h and 24 h post-slaughter in LTL and Sm muscles of 72 pigs within 3 treatments. Mean values of 24 pigs per tment, with standard error of difference (s.e.d), variance ratio (v.r.) and significance of treatment.

	Treatment					Significance
	A	B	C	s.e.d.	v.r.	
45 min	6.63^{c}	6.50^{c}	6.22^{ab}	0.070	17.81	***
3 h	6.25^{c}	6.20^{c}	5.64^{ab}	0.087	31.02	***
24 h	5.51^{c}	5.51^{c}	5.46^{ab}	0.025	2.93	NS
45 min	6.65^{bc}	6.53^{ac}	6.26^{ab}	0.063	20.98	***
3 h	6.43^{bc}	6.25^{ac}	5.87^{ab}	0.079	26.73	***
24 h	5.53	5.53	5.51	0.018	0.90	NS

le 2. Lightness (L*) and FOP values at 24 h post-slaughter in LTL and drip loss (% by wt.) over 72 h at 1°C from LTL and Sm, of 72 s within 3 treatments. Mean values of 24 pigs per treatment, with standard error of difference (s.e.d.) and variance ratio (v.r.) and nificance of treatment

		Treatment					Significance
		A	B	C	s.e.d.	v.r.	
ghtness	LTL	52.58^{c}	52.68^{c}	54.65^{ab}	0.657	6.32	**
P	LTL	12.00	11.92	15.17	1.759	2.22	NS
ip loss	LTL	3.24^{c}	3.63	4.18^{a}	0.387	2.96	NS
ip loss	Sm	1.89	2.25	2.23	0.228	1.53	NS

Table 3. Instrumental texture (Yf, Cf, W) of LTL at 4, 7 and 12d post-slaughter, and Sm at 4d post-slaughter of 72 pigs within three treatments. Mean values of 24 pigs per treatment, with standard error of difference (s.e.d.), variance ration (v.r.) and significance of treatment

	Treatment					
	A	B	C	s.e.d.	v.r.	Significance
Yield at first break (Yf)kg						
LTL						
4d	7.86^{d}	8.00^{d}	6.38^{bc}	0.466	7.44	**
7d	7.29^{d}	7.41^{d}	5.78^{bc}	0.418	9.43	***
12d	6.77^{d}	6.92^{d}	5.52^{bc}	0.422	6.61	**
Sm						
4d	8.34^{d}	7.92	7.57^{b}	0.377	2.11	NS
Compression (Cf) kg						
LTL						
4d	7.18^{d}	7.06^{d}	5.60^{bc}	0.532	5.53	**
7d	6.54^{d}	6.68^{d}	4.81^{bc}	0.485	9.20	***
12d	6.06^{d}	6.18^{d}	4.61^{bc}	0.478	6.66	**
Sm						
4d	8.10^{d}	7.44	7.28^{b}	0.388	2.51	NS
Work done (W) $J.10^{-2}$						
LTL						
4d	42.59^{d}	43.04^{d}	36.41^{bc}	2.117	6.12	**
7d	41.74^{d}	41.39^{d}	35.01^{bc}	1.993	7.23	**
12d	38.99^{d}	40.74^{d}	34.79^{bc}	1.976	4.80	*
Sm						
4d	44.80	43.63	43.06	2.117	0.35	NS

Table 4. Taste panel assessment of tenderness of griddled loin slices at 4, 7 and 12 d post-slaughter, and of roast Sm at 4d post-slaughter of 72 pigs within 3 treatments. Eight point rating scales from"extremely tough" (1) to "extremely tender" (8). Mean values of 24 pigs per treatment, with standard errors of difference (s.e.d.) and significance of treatment.

	Treatment				
	A	B	C	s.e.d.	Significance
LTL					
4d	3.64	3.83	4.28	0.203	**
7d	4.00	4.00	4.59	0.192	**
12d	4.26	4.32	4.65	0.214	NS
Sm					
4d	4.04	4.29	4.55	0.119	***