...RELATIVE EFFECTS OF ANIMAL PRODUCTION AND CARCASS PROCESSING FACTORS ON ...F TENDERNESS

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...MARY

...ims of this study were to identify key factors in commercial beef production which affect beef tenderness, and to assess their ...ive importance. As well as sex, production factors included fatness (heifers and steers) and feeding system/slaughter age ...). Carcass treatments included high- (HES), and low- (LES) voltage electrical stimulation, no stimulation (NES); pelvic bone ...suspension; slow and rapid chilling; and three ageing durations (6, 10, 14d). First yield force (Fy (kg)), work done in ...ession (W(Joules.10^{-2})), and taste panel scores (8-point scale) were obtained for loin steaks. Heifers and steers were not ...ent in tenderness, nor were fatness levels. Suckled bulls were more tender than silage bulls. The maximum production ...ences for Fy, W, and panel scores were between heifers/steers and silage bulls, with values of 1.04 kg, 4.16 J.10^{-2} and 0.49 ...l score units respectively, the bulls being tougher by all three criteria. In comparison, the maximum differences resulting from ...ive carcass processing effects in the heifer/steer data were larger. For Fy and W, the biggest differences were between NES, ...chill, 6 day ageing, and HES, slow chill, 14 day ageing, giving values of 1.72 kg and 8.94 J.10^{-2} respectively. For panel ...s, NES, rapid chill, conventional suspension (toughest) contrasted with slow chill, pelvic bone suspension (and little ...tional effect of ES), giving a maximum difference of 1.41 panel score units. It is concluded that combinations of carcass ...essing treatments can have larger effects on meat tenderness than production factors including sex, fatness and feeding system.

...RODUCTION

...ation in the tenderness of beef is a major industry problem. Modern marketing methods have accentuated the need for product ...tency, and large meat buyers, such as the major multiple retailers, have been purchasing to specifications aimed at reducing ...bility and elevating quality. However, the relative importance of the different components of a specification supposedly ...encing the eating quality of fresh meat is not well understood and, in particular, the emphasis that should be given to ...uction factors (breed, age, fatness, feeding system and sex) compared with carcass processing factors (chilling, electrical ...ulation, ageing etc.) is not clear.

There are reports that beef tenderness is affected by breed (e.g. Cundiff *et al*, 1989), age (e.g. Gerrard *et al*, 1987), ...ss (e.g. Koch *et al*, 1988), feeding system (Wood, 1990) and sex (e.g. Crouse *et al*., 1983). In the latter case, bulls, as a ...ric group, have generally been found to be tougher than castrated males (steers), but there are few data available for ...parisons between bulls produced on different systems.

Post-mortem treatments that affect tenderness include chill rate (e.g. Lochner *et al* , 1980), electrical stimulation (e.g. ...ell, 1991), carcass suspension method (e.g. Jeremiah *et al* , 1984) and ageing duration (e.g. Pearson, 1986). Some of the ...ractions of these treatments have been studied and have shown additive effects (Taylor *et al,* 1984).

This study was undertaken to quantify the effects of production factors and post mortem treatments on the tenderness of ...*ssimus thoracis et lumborum* (LTL), and to study the interactions of the various pre- and post-slaughter influences. The ...ltant information was to be used to formulate an industry-wide specification for improving the quality of British beef.

...TERIALS & METHODS

...mals. Thirty-six Hereford x Friesian heifers, and a like group of steers, were allocated to a 'lean' and a 'fat' group of 18 ...mals each, within each sex, on the basis of velocity of ultrasound measurements and assessment of fatness by handling.

Twelve barley-fed and 12 silage-fed Limousin x Friesian bulls were housed as separate groups prior to slaughter. Twelve ...kled bulls, predominantly sired by Simmental out of British beef breed x Friesian or Friesian dams, had been weaned at about ...months of age and were finished on a cereal diet. The ages of the bull groups at slaughter were known to be approximately 11, ...d 18 months for the barley, suckled and silage-fed groups, respectively.

...-slaughter treatment. All carcasses produced on one day were subjected to either high voltage electrical stimulation (HES) ...e intact dressed carcass 40 mins post-slaughter (700 volts at 25 pulses/sec for 120 sec), low voltage stimulation (LES) of the ...ly slaughtered carcass during bleeding (85 volts at 14 pulses/sec. for 64 sec), or were not stimulated (NES).

After splitting, and within one hour of slaughter, the left side of each carcass was suspended from the aitch bone (by a hook passing through the obturator foramen in the pelvis). The right sides remained suspended from the Achilles tendon.

One side of each carcass was chilled slowly (10°C, air speed 0.3m/sec for 10h, followed by 1°C, air speed 0.3m/sec to 48h post mortem), the other side rapidly (1°C, air speed 1.5m/sec for 24 h, followed by 1°C, air speed 0.3m/sec to 48h). Allocation of left or right sides to slow or rapid chilling was balanced within ES treatments.

At 48h post-mortem, a portion of LTL was divided into three equally-sized portions for texture measurements, and aged for either 6, 10, or 14 days at 3°C in a vacuum pack. From each third, a central block, approximately 7cm thick, was removed for instrumental texture measurement. Three 1.5cm-thick steaks were cut from one end of the third, and two from the other end, for taste-panel assessment.

Texture measurements. Each aged sample of muscle was cooked in a water bath until the temperature of the sample reached 78°C. A Stevens CR Analyser fitted with Volodkevich-type jaws compressing at right angles to the muscle fibres was used to record mean first yield force (kg) and the mean total work done in compression (Joules $.10^{-2}$).

The loin steaks were cooked in foil compartments on a Lincat griddle to an internal temperature of 74°C. Ten assessors received samples from one animal type, one chill type, but from three different ES treatments and two carcass suspension methods at any one session. Texture was assessed on an 8-point scale ranging from 1 (extremely tough) to 8 (extremely tender).

Data were subjected to analysis of variance using Genstat V, with blocking of sources of variation according to whether they operated between carcasses, between panels, or within carcasses. Because of differences in some sources of variation, the heifer and steer data and the bull data were analysed separately.

RESULTS AND DISCUSSION

When the sources of variation in the three tenderness parameters are restricted to those operating between carcasses, the effects of sex and fatness level (heifer and steer data only), production group (bulls only) and electrical stimulation (both groups) can be estimated. These values, which take no account of interactions with other sources of variation operating within carcasses, are shown in Table 1. There were no significant differences between heifers and steers, nor between fatness levels in those sexes. However, there were significant differences between bull production groups and ES treatments.

There were significant interactions between many of the sources of variation operating within carcasses. Examples of important and consistent interactions which include, overall, each source of variation, are included in Table 1.

Table 1. F-ratio probabilities of differences in beef tenderness owing to different sources of variation. Heifer and steer data, with bull values in parentheses, where appropriate.

Source of variation	1st yield force (kg)		Total work ($J.10^{-2}$)		Taste panel score	
A. Between carcasses						
Sex (heifers versus steers)	0.540		0.378		0.823	
Fatness (heifers and steers)	0.255		0.228		0.751	
Production group (bulls)		(0.031)		(0.097)		(0.025)
Electrical stimulation	<0.001	(0.022)	<0.001	(0.039)	<0.004	(0.011)
B. Within carcasses						
Electrical stimulation x suspension	<0.001	(<0.001)	<0.001	(0.012)	<0.001	(<0.001)
Chill rate x fat level	0.043		0.034		0.037	
Ageing duration x suspension	0.025		0.341		0.002	
Ageing duration x suspension x chill		(0.004)		(0.023)		(0.362)

Bull production group. The suckled bulls were significantly more tender than the silage-fed bulls according to all three criteria, whilst the barley bulls were intermediate and not significantly different from the other two groups (Table 2). These differences may, in part, reflect differences in age. Gerrard et al (1987) found that shear resistance increased from nine months of age but was erratic in bulls, attributed to cyclic synthesis, degradation and maturation of collagen. Other workers have shown increased toughening in bulls with age, particularly between 12 and 20 months of age (Boccard et al, 1979).

Electrical stimulation x suspension . There is an overwhelming trend in the data for the HES samples to be more tender than e 2. Effects of bull production group on beef tenderness.

ction group	1st yield force (kg)	Total work ($J.10^{-2}$)	Taste panel score
y-fed	5.46	32.74	3.99
e-fed	5.84	34.30	3.73
ed	4.70	29.80	4.47
	0.408	1.975	0.254

e 3. Interaction means of ES x suspension on beef tenderness. Heifer and steer data (bull values in parentheses)

spension	1st yield force (kg)	Total work ($J.10^{-2}$)	Taste panel score
aitch bone	4.57 (4.56)	28.18 (27.91)	4.64 (4.90)
Achilles tendon	4.05 (4.68)	26.71 (30.09)	4.24 (4.21)
aitch bone	4.70 (5.45)	29.36 (32.13)	4.49 (4.24)
Achilles tendon	5.34 (5.94)	33.30 (35.33)	3.86 (3.34)
aitch bone	4.89 (5.08)	30.43 (30.53)	4.59 (4.68)
Achilles tendon	5.23 (6.29)	32.86 (36.82)	3.53 (3.02)
sed (stimulation)	0.226 (0.430)	1.102 (2.098)	0.121 (0.265)
sed (suspension)	0.130 (0.193)	0.749 (1.001)	0.073 (0.107

LES and NES, which were not different (Table 3). Generally, aitch bone suspension resulted in more tender meat than

es tendon suspension, but the reversal in first yield force and total work for the HES sides resulted in the significant sions. The import of this finding is questionable when no such pattern occurs in the bull data, and the taste panel scores e more tender meat from the aitch bone suspended sides. However, the differences in tenderness between the two sion methods are generally smaller in HES than in the other treatments.

rate x fatness level. In the heifer and steer data, there were significant interactions between chill rate and fatness level three tenderness parameters ($p<0.043$). These results (Table 4) show that in the lean group, slow chilling resulted in cantly more tender meat by all three criteria, whereas in the fatter group these differences, although tending to favour the chill, were not statistically significant ($p>0.05$). These findings tend to confirm the hypothesis that the major role of fat in ing tenderness is the insulating effect which reduces the likelihood of cold shortening (Marsh 1977).

e 4. Interaction means of chill rate x fatness level on beef tenderness - heifers and steers only

rate/fatness level	1st yield force (kg)	Total work ($J.10^{-2}$)	Taste panel score
rs and steers - lean			
slow chill	4.65	29.29	4.34
fast chill	5.14	31.96	4.09
rs and steers - fat			
slow chill	4.61	29.25	4.29
fast chill	4.79	30.07	4.19
sed	0.185	0.899	0.096

g duration x suspension. In the heifer and steer data, ageing duration x suspension was significant for first yield force ste panel score ($p<0.025$). The basis of the interaction was the same in both cases, namely the weakening of the advantage in ess gained through aitch bone hanging as ageing duration increased (Table 5). Ageing itself generally improved tenderness.

Table 5. Interaction means of ageing duration x suspension on beef tenderness. Heifer and steer data (bull values in parentheses)

Ageing duration/suspension		1st yield force (kg)	Total work ($J.10^{-2}$)	Taste panel score
6 days	aitch bone	4.79 (5.34)	29.95 (30.79)	4.61 (4.63)
	Achilles tendon	5.13 (5.76)	32.01 (34.68)	3.72 (3.48)
10 days	aitch bone	4.69 (5.04)	28.86 (30.76)	4.59 (4.60)
	Achilles tendon	4.95 (5.70)	30.97 (34.09)	3.91 (3.57)
14 days	aitch bone	4.68 (4.71)	29.16 (29.01)	4.52 (4.58)
	Achilles tendon	4.55 (5.45)	29.90 (33.47)	4.00 (3.53)
	sed	0.130 (0.509)	0.749 (1.001)	0.073 (0.107)

Maximum contrasts between treatment combinations. The largest differences between factors affecting beef tenderness at the animal production level occurred when silage-fed bulls were contrasted with the pooled heifer/steer data. These differences in first yield force, total work and taste panel score were 1.04kg, 4.16 $J.10^{-2}$ and 0.49 score units, respectively (Table 6). When the effects of post-mortem treatments (heifer and steer data only) were examined, the biggest contrasts for first yield force and total work were between NES, rapidly chilled, 6-day aged samples and HES slowly chilled, 14-day aged samples, the former combination yielding meat which was 1.72kg and 8.94 $J.10^{-2}$ tougher, respectively. For panel scores, the contrast was between NES, rapidly chilled, Achilles tendon suspension(toughest) and slowly chilled, aitch bone suspension (with HES being marginally more tender than other ES), giving a difference of 1.41 panel score units.

CONCLUSIONS

The range of carcass types used in this study, although not representing biological extremes in terms of age, weight, or indeed breed type does, nonetheless, typify a wide cross-section of commercial beef production in the UK. The maximum differences between these carcass types in instrumental meat texture measurements and sensory panel scores, may be exceeded by a factor of up to three when extreme combinations of carcass treatments are compared.

Table 6. Maximum contrasts between factors affecting beef tenderness (A) production factors and (B) post-mortem treatments

Maximum contrast		1st yield force (kg)	Total work ($J.10^{-2}$)	Taste panel score
A.	Heifers/steers	4.80	30.14	4.22
	Silage-fed bulls	5.84	34.30	3.73
	Difference	1.04	4.16	0.49
B.	NES x rapid x 6 days ageing	5.63	35.06	
	HES x slow x 14 days ageing	3.91	26.12	
	NES x rapid x Achilles suspension			3.25
	HES x slow x aitch bone suspension			4.66
	Difference	1.72	8.94	1.41

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