HOT DEBONING BEEF WITH AND WITHOUT ELECTRICAL STIMULATION

A.A. TAYLOR, B.G. SHAW and D.B. MacDOUGALL

Meat Research Institute, Langford, Bristol.

INTRODUCTION

MUCH of the weight lost during cooling of beef sides can be saved if the meat is deboned as soon as possible after slaughter and vacuum packed before chilling. Less refrigeration is required to cool the meat and large carcass chillers can be replaced by more compact units with better control over cooling rates. Joints can be chilled more rapidly and evenly and this should reduce exudate or drip loss and give more uniform colour within joints.

Hot deboned meat is, however, sticky and more liable to contamination than cold deboned and, although packs chill more rapidly than carcasses, contaminated surfaces are often deep in the pack and their slower cooling rates give more opportunity for bacterial multiplication. Eating quality may also be affected since rapid chilling increases the risk of cold shortening and this can cause toughness (Locker & Hagyard, 1963; Marsh & Leet, 1966; Dransfield & Jones, 1978).

This study was designed to analyse all the apparent advantages and disadvantages of hot deboning as a commercial practice. Conventional deboning after chilling was compared with two hot deboning treatments designed to allow faster chilling without cold-shortening, under conditions which could be achieved by current factory equipment.

EXPERIMENTAL

MATERIAL Sixteen Hereford, Friesian or Hereford x Friesian steers, aged between 1½ and 2½ years (carcass weights 245 to 360 kg) were used. One side of each carcass was cold deboned and the opposite sides were hot deboned, eight after electrical stimulation (Davey, Gilbert & Carse, 1976). Temperatures were measured in the deep round and on the surface of sides, and in the centre and surface of the hot deboned topside joints.

Treatments Cold deboning (C) Sides were held at 15°C for 7 hr before being placed in a chillroom at 0° to 1°C and an air velocity of 0.5 m/sec. At 48 hr from slaughter they were deboned into 15 primal joints (shin, clod neck, brisket, shoulder, forerib, chuck, leg, topside, silverside, top rump, rump, fillet, strip loin, hind-quarter flank), which were vacuum packed in Cryovac BBI bags. Hot deboning (H) Sides were hot deboned, 1-2 hr after slaughter and the 15 primal joints vacuum packed immediately. At 3 hr from slaughter the joints were chilled in single layers in plastic mesh trays at 10°C with an air velocity across the meat of 0.5 m/sec for 9 hr and then at 1°C for a further 18 hr. Hot deboning after electrical stimulation (E) Approximately 50 min from slaughter, 700 v at 25 pulses/sec were applied to the sides between the Achilles tendon and the neck for four 30 sec periods. The pH in M. longissimus dorsi fell to 6.5 (mean for all stimulated sides). Hot deboning was carried out 1-2 hr after slaughter and the vacuum packed joints were chilled on trays in air at -1°C with an air velocity across the meat of 0.5 m/sec until 24 hr from slaughter.

In all cases the chilled joints were stored in cartons at +1°C. Joints from eight of the animals were examined after 5 days and joints from the other eight after 21 days.

Meat Yield Sides were weighed at the end of the dressing line and all hot deboned joints, lean trim, kidney, fat trim and bone were weighed before chilling. Chilled sides were weighed before cold deboning and joints, etc. were weighed before storage. When vacuum packs were opened, joints and residual drip were weighed.

Microbiology The surfaces of all joints were sampled before packing and at the end of storage by swabbing 100 cm^2 using the template and swab technique (Kitchell, Ingram & Hudson, 1973) with sterile saline containing 0.1% peptone as diluent. Decimal dilutions were made from each swab by the loop/tile method (Kitchell et al., 1973) and 0.02 ml of each dilution plated on Plate Count Agar (PCA, Oxoid) which was incubated at 25°C for 5 days to obtain the total viable count. Escherichia coli were enumerated as described by MacDougall et al., (1979).

Texture Samples were taken from M. longissimus dorsi, M. semitendinosus, M. gluteus medius and M. psoas major, vacuum packed and heated at 80°C for 20 to 30 min until they reached 79°C, cooled for 30 min and cut into 1 x 1 x 3 cm blocks. An Instron Universal Testing machine fitted with Volodkevich jaws recorded toughness as the mean work done (J) in compression through the 1 cm^2 cross sections of 10 replicates at right angles to fibre direction of 10 replicates.

Sarcomere length The sarcomere lengths of raw myofibrils were measured by optical diffraction using a helium-neon laser (Voyle, 1971). Mean length (µm) was calculated from 6 replicates from 4 sites from a 1 cm slice of M. longissimus dorsi.

Colour 2 cm slices of M. longissimus dorsi and M. semimembranosus were wrapped in oxygen permeable film and exposed to air for 1 hr at 2°C. The M. semimembranosus sample included the layer below the subcutaneous fat and the portion adjacent to the femur. Colour was measured with a Hunter D25 Colour Difference Meter and the results expressed as uniform lightness, hue and saturation (Taylor & MacDougall, 1973).
Lightness was also measured on a transverse section of chilled lumbar subcutaneous fat.

Pigment content and pH Total pigment was measured as cyanmetmyoglobin (Wierbicki et al., 1955) and pH was determined in the 1 : 9 distilled water extract.

Organoleptic assessment Pairs of rolled sirloin joints, approximately 15 cm in diameter, from control and treated sides of the same animal were roasted to an internal temperature of 75°C in electric ovens at 175°C. Slices of trimmed M. longissimus dorsi 0.5 cm thick were served hot to a 13 member panel experienced in assessing roast beef. Flavour was assessed on an 8-point scale from like extremely to dislike extremely. Texture was assessed on an 8-point from extremely tender to extremely tough and juiciness on a 5-point scale from extremely juicy to dry.

Experimental design The experimental design is a partially balanced incomplete block in which treatment H was compared with C on 8 carcasses and treatment E was compared with C on 8 carcasses, 4 of each of the 8 carcasses being examined at 5 days or 21 days. The means of the main effects from the analysis of variance are presented.

RESULTS

CHILLING Time x temperature relationships are shown in Table 1. With treatments H & C, the temperatures

Table 1. Time x temperature relationships for deep and surface musculature during cooling in treatments C, H & E

	Treatment		
	C	H	E
Temperature (°C) at 12 hr from slaughter (surface)	12	14	4
" " " " " " " (deep)	26	19	13
Time (hr) to reach 7°C (deep)	34	21	17
" " " " 2°C "	48	32	23

12 hr after slaughter were sufficiently high to avoid cold shortening. With treatment E, the lower temperatures would have induced shortening in a considerable proportion of the meat had it not been stimulated.

A deep temperature of 7°C was achieved 17 hr after slaughter with E, and even with the delayed chilling in H, was reached in 21 hr compared with 34 hr with the conventionally chilled sides.

Meat Yield The hot deboning procedures used for treatments H & E were identical and their data were combined for comparison with conventional cold deboning (Table 2). Because the hot and cold butchery was slightly different, the weights of joints from each treatment were combined with lean trim as total usable meat. The yield of meat based on hot side weight was significantly greater ($p<0.001$) with hot deboning, mainly because the 1.7% evaporative loss during the chilling of sides was avoided and 2.6% less fat was trimmed from the hot primal joints before vacuum packing. On the other hand there was 0.4% greater evaporative loss during deboning, jointing and packing of the hot meat. The weight of bone was also 1.3% greater than from the cold sides,

Table 2. Comparison of cold and hot deboning on meat yield from opposite sides of 16 animals (% hot wt.)

	Hot side	Cold side	Usable meat	Bone	Fat Trim	Evaporation loss during chilling	Evaporation loss during boning, jointing and packing
Cold deboned	100	98.3	73.6	16.3	8.2	1.7	0.2
Hot deboned	100	-	76.2	17.6	5.6	-	0.6

possibly because the bone in the latter had dried during chilling, but more likely because of less efficient trimming with hot deboning.

Drip Little drip accumulated in vacuum packed joints during the first 5 days of storage (Table 3), but by 21 days it had increased in both forequarter and hindquarter cold deboned joints, although with hot deboning it

Table 3. Effect of treatments C, H and E on accumulation of drip (% packed wt.) in joints stored for 5 or 21 days at 1°C.

	5 days			21 days		
	C	H	E	C	H	E
Forequarter joints	0.06	0.16	0.08	0.32	0.20	0.20
Hindquarter joints	0.16	0.05	0.05	0.42	0.12	0.32
All joints	0.11	0.11	0.07	0.37	0.16	0.26

increased only in the electrically stimulated hindquarter joints. Altogether hot deboning reduced drip loss, but to a lesser extent when electrical stimulation was used.

Microbiology Bacterial counts on the joints at the time of packing (initial) and after storage are shown in Table 4. The method of deboning did not affect ($p>0.05$) the initial level of contamination and there was no

Table 4. Effect of treatments C, H and E on initial and final bacterial counts ($\log_{10}$ number cm^2) on joints stored for 5 or 21 days at 1°C.

	Initial			5 days			21 days		
	C	H	E	C	H	E	C	H	E
Total count	2.41	2.68	2.43	2.25	2.65	2.41	4.31	4.68	3.97
E. coli	0.02	0.02	T.99	0.04	0.04	T.96	0.03	0.02	0.01

treatment effect ($p>0.05$) on total viable counts or numbers of *E. coli* after storage.

Instrumental measurement of texture and colour After only 5 days the four muscles gave texture values typical of relatively tender meat (Table 5). Roast beef assessed by an experienced taste panel as very tender,

Table 5. Effects of treatments C, H and E on colour of fat and raw *M. longissimus dorsi*, sarcomere length, texture measurement of 4 muscles of rolled sirloin roast after 5 or 21 days at 1°C.

	5 days			21 days		
	C	H	E	C	H	E
Subcutaneous fat						
Lightness	67.1	70.1	68.8	67.5	70.8	69.5
M. long. dorsi						
Lightness	29.8	30.2	29.4	31.5	31.7	31.5
Hue	26.2	26.4	25.8	26.5	26.3	26.6
Saturation	19.6	19.9	19.3	21.8	22.2	22.3
Sarcomere length (μm)	1.59	1.60	1.56	1.63	1.69	1.62
Texture (J)						
M. long. dorsi	0.18	0.17	0.21	0.15	0.12	0.16
M. semitendinosus	0.12	0.22	0.24	0.18	0.19	0.17
M. gluteus medius	0.18	0.15	0.19	0.16	0.13	0.11
M. psoas major	0.14	0.13	0.16	0.13	0.12	0.13

slightly tender and slightly tough would have values measured by this method of approximately 0.14, 0.19 and 0.25 J respectively. Texture improved between 5 and 21 days but with no consistent difference between treatments and this, together with measurements of sarcomere lengths in *M. longissimus dorsi* confirmed that cold shortening had not occurred.

Fat packed hot in treatments H and E was lighter than fat removed cold in treatment C. The colour of *M. longissimus dorsi* was unaffected by treatment and the increases in lightness and saturation with storage were similar.

Colour may vary within large muscles because differences in cooling rate affect light scattering and therefore lightness (MacDougall, 1977). The ultimate pH and pigment content of *M. semimembranosus* was affected neither by treatment nor by position within the muscle but lightness varied with position. With cold deboning, the inner part of the muscle was lighter than the outer; with treatment H there was no difference between inner

Table 6. Effect of treatments C, H and E on pH and lightness of 2 anatomical locations (3 cm below subcutaneous fat = OUT; 3 cm in from femur = IN) in *M. semimembranosus* stored for 5 and 21 days at 1°C.

		5 days			21 days		
		C	H	E	C	H	E
pH	OUT	5.55	5.50	5.58	5.54	5.52	5.56
	IN	5.60	5.55	5.63	5.53	5.60	5.56
Lightness	OUT	27.6	26.6	26.4	28.6	28.6	27.5
	IN	32.4	26.7	30.5	32.4	28.6	30.6

and outer; with treatment E, the inner was lighter than the outer, but less so than in treatment C.

Panel assessment of eating quality An experienced panel found no differences with treatment in either flavour or juiciness; texture of roast *M. longissimus dorsi* was also unaffected by treatment and the improvement from 5 days when it was judged "moderately tender" to 21 days when it was approaching "very tender" was similar for all treatments.

DISCUSSION

Hot deboning avoids weight loss during carcass chilling, but part of the advantage is offset by evaporation from the hot meat during deboning and packing. In these experiments weight loss was 0.6% in 1-1½ hr, but it could be reduced with quicker procedures. Reduced evaporative loss resulted in more usable meat, but yield was also affected by differences in hot and cold butchery. It was impossible to carry out normal fat trimming during hot deboning (Schmidt & Keman, 1974), and fat may have to be removed at retail. Fat trim cannot be considered as usable meat and, if the 2.6% difference in fat trim between hot and cold deboning is subtracted from the total meat from hot deboning, the yield is identical for the two methods. The remaining overall saving in evaporative loss (1.3%) was offset by the greater bone weight from hot butchery, suggesting that meat yield will not be improved unless the bone is trimmed as efficiently as with cold deboning.

Hot deboning coupled with more rapid cooling minimized drip loss and produced a more even colour across large muscles. These benefits however were less when electrical stimulation was included, suggesting that the early fall in pH increased protein denaturation. The greater drip from hindquarter joints which were the last to be removed from the carcass, and the paler colour of the interior leg muscle, demonstrate that this denaturation occurred in part while the meat was still on the carcass.

There is no evidence that hot deboning increases bacterial contamination before packing, or that initial chilling at 10°C for 12 hr is likely to allow growth of bacteria hazardous to health. Total viable counts during storage were similar to those on cold deboned joints and shelf life should be comparable. Higher temperatures or longer conditioning periods may have considerable adverse effects on microbiological quality and this stage requires careful control. Single stage low temperature chilling, after electrical stimulation, avoids this problem.

Although Dransfield, Brown & Rhodes (1976) found that instrumental measurement of toughness was increased slightly by hot deboning, we detected no treatment difference in texture of the muscles we examined and, also confirmed that hot deboning did not affect juiciness, flavour or texture assessed by taste panel. There was no indication of any direct tenderising effect from electrical stimulation. Reports of improved tenderness (Harsham & Deatherage, 1951; Savell, Smith & Carpenter, 1978) have been associated with slow cooling, and George, Bendall & Jones (1979) attributed the effect to high muscle temperature at onset of rigor. Any tenderising effect would therefore be minimal or undectable with the rapid chilling used in this study.

In the UK, the principal commercial attraction of hot deboning may prove to be the considerable reduction in time, space and refrigeration capacity required for chilling. Risk of cold shortening can be avoided by delaying the start of chilling, but maximum saving in time is achieved by combining hot deboning with electrical stimulation. The meat from beef carcasses can therefore be chilled to the 7°C required by the EEC well within a daily cycle.

REFERENCES

Davey, C.L., Cilbert, K.V. & Carse, W.A. (1976) N.Z. J. Agric. Res. 19, 13.
Dransfield, E., Brown, A.J. & Rhodes, D.N. (1976) J. Fd Technol. 11, 401.
Dransfield, E. & Jones, R.C.D. (1978) J. Sci. Fd Agric. 29, 601.
George, A.R., Bendall, J.R. & Jones, R.C.D. Meat Sci. (in press).
Harsham, A. & Deatherage, F.E. (1951) U.S. Patent 2, 544, 681.
Kitchell, A.G., Ingram, G.C. & Hudson, W.R. (1973) Sampling - Microbiological Monitoring of Environments, 48, Academic Press, London & New York.
Locker, R.H. & Hagyard, C.J. (1963) J. Sci. Fd. Agric. 14, 787.
MacDougall, D.B. (1977) Colour in meat. In Sensory properties of foods, (Birch, G.G., Brennan, J.G. & Parker, K.J., eds), 59.
MacDougall, D.B., Shaw, B.G., Nute, G.R. & Rhodes, D.N. (1979) J. Sci Food Agric. 30, 1160.
Marsh, B.B. & Leet, N.G. (1966) J. Fd Sci. 31, 450.
Savell, J.W., Smith, G.C. & Carpenter, Z.L. (1978) J. Fd Sci. 43, 1666.
Schmidt, G.R. & Keman, S. (1974) J. Fd Sci. 40, 140.
Taylor, A.A. & MacDougall, D.B. (1973) J. Fd Technol. 8, 453.
Voyle, C.A. (1971) Proceedings of 17th European Meeting of Meat Research Workers, Bristol, 95.
Wierbicki, E., Cahill, V.R., Kunkle, L.E., Klosterman, E.W., Deatherage, F.E. (1955) J. Agric. Fd Chem. 3, 245.