THE EFFECTS OF CHILLING RATE, SUSPENSION AND AGING ON BEEF QUALITY

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18 two-tooth Hereford heifers, (av. carcass weight 203 kg) were assigned at random to three chilling rates, with six animals to each rate. The sides of each carcass were assigned at random to normal suspension and 'tenderstretch' suspension, i.e. by the aitch bone. 48 h post mortem six major meat muscles, LD, PS, BF, ST, SM, and GM were dissected out and divided into three parts which were assigned at random to aging periods of 2, 7 and 14 days post mortem. Aging was in vacuo at 2°C. After aging, the meat was tested for tenderness by a taste panel and shear meter. Carcass weight loss and bacteriological status were also measured. Sarcomere length was measured in the six muscles.

Rapid chilling induced increased toughness in LD. This was reduced by tender stretching and aging. PS was slightly toughened by tenderstretching, not affected by chilling and slightly tenderised by aging. SM was tenderised by aging and by tenderstretching, but not by slower chilling. GM was slightly tenderised by tenderstretching and aging while BF and ST were not affected by any treatment.

Carcass weight losses were greatest in the medium and slow chilling groups. Sarcomere lengths were all significantly increased by tenderstretching except in PS where they were significantly decreased. Chilling rate did not affect sarcomere lengths significantly.

The connection between sarcomere length changes and toughness changes is marked in LD, PS, SM, and GM but not in BF or ST. Rapid chilling was not found to produce significant sarcomere shortening but was associated with toughening in LD.

Tenderstretching, slower chilling and aging can be used singly or in combination by the more intensively managed sections of the beef industry to enhance the tenderness of their product.

EFFETS DE LA VITESSE DE REFROIDISSEMENT, DE LA SUSPENSION ET DE LA MATURATION SUR LA QUALITE DE LA VIANDE DE BOEUF

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18 genisses Hereford a deux dents (poids moyen de la carcasse: 203 kg) ont ete soumises au hasard a trois vitesse de refroidissement, a raison de six animaux pour chaque vitesse. Les demi-gros de chacune des carcasses ont ete soumis, au hasard, a une suspension normale et a une suspension en 'etirage d'attendrisment', c'est a dire par culotte. 48 h post mortem, six muscles majeur de la viande, LD, PS, BF, ST, SM, et GM ont ete dissectes et divises en trois sections qui ont ete soumises, au hasard, a des periodes de maturation de 2, 7, et 14 jours post-mortem. La maturation a eu lieu in vacuo a 2°C. Apres maturation, la viande a ete soumise a des tests de tendrete par un jury charge du gout et par un appareil mesureur. Les pertes de poids de la carcasse et le statut microbiologique ont ete egalement mesures. La longeur du sarcomere a ete mesure dans les six muscles.

Le refroidissement rapide provoque a augmente la durete dans LD. Celle-ci a ete reduite par l'etirage d'attendrissement et la maturation. PS a ete legerement durci par l'etirage d'attendrissement, n'a pas ete affecte par le refroidissement et a ete legerement attendri par la maturation. SM a ete attendri par la maturation et l'etirage d'attendrissement, mais pas par le refroidissement plus lent. GM a ete legerement attendri par l'etirage d'attendrissement et la maturation, tandis que BF et ST n'ont ete affectes par aucun traitement.

Les pertes de poids de la carcasse ont ete plus grandes dans les groupes de moyen et lent refroidissement. Les longueurs du sarcomere ont tout ete notablement augmentees par l'etirage d'attendrissement excepte dans PS ou elles ont ete notablement diminuees. La viteese de refroidissement n'a pas affecte de facon notable les longueurs du sarcomeres.

Le rapport entre les changements de logueur du sarcomere et les changements de durete est marque dans LD, PS, SM, et GM, mais pas dans BF ou ST. Le refroidissement rapide ne s'est pas avere produire un racourcissement notable du sarcomere mais il a ete associe a un durcissement dans LD.

L'etirage d'attendrissement, le refroidissement plus lent et la maturation peuvent etre utilises separement ou de facon combinee par les secteurs de l'industrie bovine plus intensifs pour accroitre la tendrete de leur produit.

DIE WIRKUNG VON KÜHLVERHÄLTNIS, AUFHÄNGUNG UND ABLAGERUNG AN RINDFLEISCH QUALITÄT.

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18 zwei-Zahn Hereford Färsen, (durchschnittliches Kadaver Gewicht 203 kg) wurden aufs Geradewohl zu drei Kühlungswerten bestimmt, mit sechs Tieren für jeden Wert. Die Seiten jeden Kadavers wurden blindlings ausgewählt für normale Aufhängung und Weichausdehnung Aufhängung, d.h. am Beckengürtel. 48 h. nach dem Tod sechs Hauptfleischmuskeln, LD, PS, BF, ST, SM und GM wurden herausseziert und in drei Teile geteilt, welche aufs Geradewohl drei Ablagerungszeiten von 2, 7 und 14 Tagen nach dem Tode unterworfen wurden. Ablagerung war in vacuo bei 2°C. Das Fleisch wurde nach Ablagerung von einem Geschmackskollegium und Schnitter auf Zartheit geprüft. Kadavergewichtsverlust und bakteriologischer Zustand wurden ebenfalls gemessen. Beckengürtellange wurde in den sechs Muskeln gemessen.

Schnelle Kühlung verursachte erhöhte Zähigkeit in LD. Dies wurde durch Weichausdehnung und Ablagerung reduziert. PS wurde leicht zäher durch Weichausdehnung, nicht berührt von Kühlung und geringfügig weicher durch Ablagerung. SM wurde weicher gemacht durch Ablagerung und Weichausdehnung, aber nicht durch langsamere Kühlung. GM wurde kaum weicher durch Weichausdehnung und Ablagerung, während BF und ST von keiner Behandlung berührt wurden.

Kadavergewichtsverluste waren am grössten in den mittleren und langsameren Kühlungsgruppen. Beckengürtellangen waren alle bedeutend erhöht durch Weichausdehnung, ausser in PS, wo sie bedeutend abnahmen. Kühlungsverhältnis hatte auf Beckengürtellange keinen bedeutenden Einfluss.

Die Verbindung zwischen Beckengürtellange-Veränderungen und Zähigkeitsveränderungen ist beträchtlich in LD, PS, SM und GM, aber nicht in BF oder ST. Schnelle Kühlung erwirkte keine bedeutsame Beckengürtellängeverkürzung, wurde aber mit der Zähigkeit in LD in Verbindung gebracht.

Weichausdehnung, langsamere Kühlung und Ablagerung kann einzeln gebraucht oder kombiniert werden mit den mehr intensiv geführten Abteilungen der Rindfleisch-Industrie, um die Zartheit ihrer Produkte zu erhöhen.

ЭФФЕКТЫ СКОРОСТИ ЗАМОРАЖИВАНИЯ, ПОДВЕШИВАНИЯ И СОЗРЕВАНИЯ НА КАЧЕСТВО МЯСА КРУПНОГО РОГАТОГО СКОТА

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I8 двухзубных телок породы Херефорд, средним весом туши в 203 кг, распределились по шести наобум трем скоростям замораживания. Половины туш подверглись нормальному подвешиванию и т.н. "тэндерстрэчинг", т.е. подвешиванию с крестцовой кости. Спустя 48 часов после убоя, шесть главных мышец LD,PS,BF,ST,SM, и GMвырезались и делились в три части, которые распределились наобум разным срокам созревания в 2, 7, и I4 дней после убоя. Созревание проводилось в вакууме при 2°C. После созревания мясо испыталось для мягкости с помощью вкушающей группы и измерителя сдвига. Определились также потери веса туши и бактериологическое состояние. Во всех шести мышцах измерилась длина саркомеры.

Ускоренное замораживание вызвало увеличенную жесткость в LD, а это уменьшилось путем тэндерстрэчинг и созревания. Что касается PS тэндерстрэчинг немного увеличилась жесткость, замораживание никакого эффекта не имело, а созревание немного улучшило мягкость. Мягкость SMулучшилась со созреванием и тэндерстрэчинг, но не за счет замедленного замораживания. Мягкость GM немного улучшилась путем тэндерстрэчинг и созревания, но на BF и ST никакого эффекта не произвелось.

Потери веса туши оказались наибольшими в группах среднего и замедленного замораживания. Во всех случаех увеличились длины саркомеры за счет тэндерстрэчинг, с исключениемPS, где произошло значительное уменьшение. Скорость замораживания не оказала значительного влияния на длины саркомеры.

Связь между изменениями длины саркомеры и жесткостью более заметна в LD PS SM и GM по сравнению с BF или ST. Ускоренное замораживание не вызвало значительного укорачивания длины саркомеры, но имело отношение к увеличенной жесткости в LD.

Более прогрессивные отрасли мясной промышленности могут воспользоваться тэндерстрэчинг, замедленным замораживанием и созреванием, все вместе или отдельно, для того, чтобы улучшить мягкость готового продукта.

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INTRODUCTION

The treatment of a beef carcass after slaughter has an important effect on quality. Since a contracted muscle gives toughened meat, it is advantageous to ensure that muscles do not contract to an excessive degree during rigor onset. Suspension of the carcass by the aitch-bone ("tenderstretch") stretches muscles on the back and on the outside of the hip joint and they pass into rigor with longer sarcomeres than in corresponding muscles on normally suspended carcasses. This stretching has a tenderising effect on the meat. (1,2,3,4). "Conditioning" involves holding carcasses during the onset of rigor at temperatures high enough to prevent the meat cooling to below 11°C before rigor, and by this means stops cold shortening and toughening. (5,6). Post-rigor aging in the chill cannot affect muscular contraction but it allows natural autolytic breakdown of sarcomere structure to occur with a consequent tenderising of the meat. (7,8,9).

The three methods of tenderising have certain disadvantages. Tenderstretching produces an odd-shaped hindquarter with the limb at right angles to the back bone. Conditioning increases the risk of bacterial growth on the surface and at the bone, (10), as well as increasing weight loss by evaporation. (11). Aging (12) allows psychrophillic bacterial growth and possible spoilage, and further weight loss; it also ties up capital.

The relative effectiveness of the three methods, which may differ from muscle to muscle, will determine their commercial acceptability. It is important also to determine whether the methods are additive in their effects or even synergistic. In the experiment reported here we combined the 3 tenderising methods and subsequently examined meat quality in 6 major muscles. Sarcomere lengths have been measured to determine the effect of tenderstretching and chilling rate on the degree of contraction. We have also measured bacterial growth and carcass weight loss since the extent of these may affect the commercial usefulness of conditioning.

Experimental Procedure

18 Hereford heifers with 2 adult teeth, aged about 18 months to 2 years were assigned at random, six per group, to 3 chilling rates, slow, medium and fast. The sides, left and right, were assigned at random to tenderstretch and normal suspension. After slaughter fast chilling was effected by transfer into a laboratory chill with an air flow of 1 m sec^{-1} at 0°C for 48 hours. Medium chilling was effected by holding the carcass in the room at 14°-20°C for 24 hours before transfer to the chill for a further 24 hours. Slow chilling was effected by enclosing the carcass in a box of expanded polystyrene 2.5cm thick for 24 hours in the room before transfer to the chill.

48 hours post-mortem six muscles of the hind, longissimus dorsi (LD), psoas major (PS), biceps femoris (BF), semi-tendinosus (ST), semi-membranosus (SM) and glutaeus medius (GM), were dissected out and each was divided into 3 roughly equal sections. These were assigned, also at random, to 2,7 and 14 days post-mortem aging. Small pieces were removed from each section for sarcomere length determination. After weighing, the 7 and 14 day sections were sealed in Swiss-Vac(R) to be held at 2°C. From the front of the 2 day section a steak 2.5cm thick was cut with face perpendicular to the fibre bundles. The other two sections were similarly sampled at the end of their aging period.

Bacteriology Swabs were taken in 100 cm^2 areas on the outer surface of carcasses at 6 points, the round, near the quarter point and the neck on both sides. The swabs were put into 20 ml ¼ strength Ringer's diluent and serial 10 fold dilutions were made, up to 10^{-3}. These were plated out on Oxoid plate count agar. They were grown at 25°C for 3 days and then counted.

Cooking Steaks were trimmed to fit in circular tins 10 cm X 2.5 cm and were sealed in Swiss Vac bags. The bags were immersed in water for 40 min at 80°C, then withdrawn into water at 10°C for 1 hour. (14).

Shearing Dice 20 X 10 X 10 mm were cut from the cooked meat with the fibres parallel to the long axis. They were measured with a micrometer and then sheared in half by the Volodkevich (15,16) shear meter. Total work to shear (VW) and maximum force employed, (VF) were found from the force distance diagram drawn by the shear meter.

Taste Panel The sheared pieces were put to a taste panel. Each judge received a piece from a tenderstretch muscle and a piece from the correspondingly aged section of the normally hung muscle. The judges scored on a nine point scale for tenderness-toughness.

	very tough		slightly tough		slightly tender		very tender	
extremely tough		tough		intermediate		tender		extremely tender
0	1	2	3	4	5	6	7	8

Sarcomere length Small pieces of muscle (2.5 mg) were homogenized with 1 ml ¼ strength Ringer solution. The suspensions were examined directly by projection on a screen at fixed magnification and the sarcomere lengths found by counting the number of sarcomeres in 10 cm of image.

RESULTS AND DISCUSSION

Figure 1 gives the average cooling curves for the three chilling treatments. At 10 hours post mortem, 'fast' chilling had effected a significantly greater cooling than the other two in both quarter point and round. The LD at the quarter point was just below 10°, and was thus at risk for cold shortening. (Bendall 1972). The average weight losses produced by the three treatments were; fast 1.2%, medium 1.6% and slow 1.5%, though these were not significantly different. Humidity in the "hot box" used for slow chilling was 100% which presumably reduced weight losses therein. The mean carcass hot weight was 209.9 kg. The heaviest carcass was 243.8 kg, the lightest 171.4 kg.

TABLE 1 Numbers of Total Viable Counts, falling within ranges (in organisms cm^{-2}). Results from three sites pooled.

	chilling rate								
	slow			medium			fast		
swabbed	$<10^2$	10^2-10^4	10^4	$<10^2$	10^2-10^4	10^4	$<10^2$	10^2-10^4	10^4
24h p.m	18	18	0	15	21	0	20	13	0
48h p.m	8	20	8	11	21	4	20	10	3

Table 1 gives total viable counts expressed as the numbers of counts falling within ranges of number of organisms. cm^{-2}. No counts exceeded 10^5 at 48h p.m. Fast chilling produced fewest counts in the highest ranges. No signs of surface infection were noticed in any carcasses but one instance of "bone taint" was recorded round the right femur of an animal which had been slowly chilled. No smells, slime or discolouration were found on the 7 and 14 day Swiss-Vac bags.

Table 2 gives sarcomere lengths. Tenderstretching significantly shortens the PS sarcomeres and lengthens all others. Chilling rates did not affect sarcomere lengths.

Table 3 gives taste panel scores and shear meter force and work. In general where means do not differ significantly a common mean is quoted. However in LD all means are quoted to show that although overall chilling

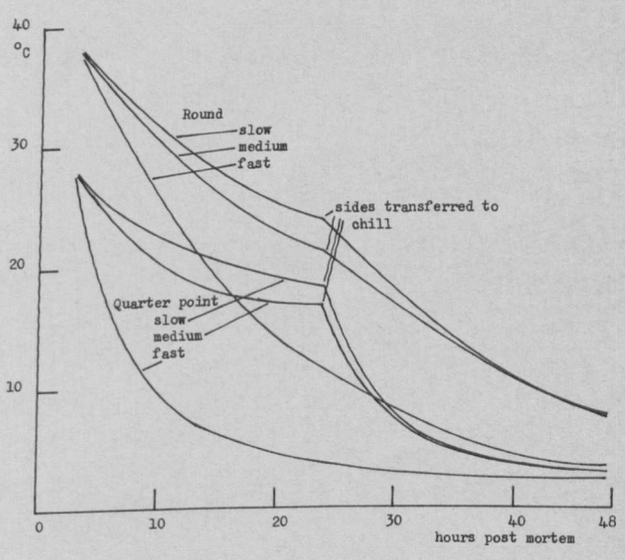

Figure 1. Measured average cooling curves for the three chilling treatments measured in the centre of the deep round and in the LD at the quarter-point (11/12 rib).

TABLE 2 Sarcomere lengths.

	sarcomere length (μM)					
suspension	LD	PS	BF	ST	SM	GM
tenderstretch	2.38	2.56	2.86	2.40	2.73	2.59
normal	1.79	3.29	1.86	2.16	1.79	1.73

Suspension effects were all significant at 1% except ST, 5%. Chilling rate had no effect.

rate had no significant effect, at 2 days post mortem, rapid chilling significantly decreased taste panel score and increased shear force and work. This effect was reduced at 7 days and was only slight at 14 days p.m. Chrystall (17) has observed that sarcomere length is not a good indication of mechanical properties or of sensory ratings. Toughness induced by fast chilling was not necessarily associated with shorter sarcomeres although Bendall (5) has recorded the presence of nodes of shortened sarcomeres in tough LD from rapidly chilled lamb carcasses.

In PS tenderstretch suspension reduces tenderness. The muscle is on the ventral side of the spine and hip and the sarcomeres are shortened. In BF and ST although the sarcomeres are lengthened there is no detectable effect on toughness. Both SM and GM are more tender if tenderstretched but the effect in the latter was detected only by the shear meter. The effects of aging on tenderness are significant in LD in all three parameters. In other muscles aging effects are not uniform.

All three methods of tenderising could be of use commercially in an advanced meat factory. High standards of hygiene and control of refrigeration would be essential if slower chilling is to be exploited. Tenderstretching would seem to be of most use at present to factories where carcasses are divided into primal cuts before shipping. Aging should be applied only to certain muscles. The extra profitability conferred by guaranteeing tenderness should be quantified, in order to determine the commercial value of the three methods.

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TABLE 3 Taste Panel Scores, Shear Meter Force and Work

LD	Tenderstretch			Normal		
	Score	Force (N)	Work (J)	Score	Force (N)	Work (J)
s 2	4.80	74.7	0.360	4.07	99.4	0.443
7	5.20	62.9	0.365	4.60	86.0	0.367
14	5.67	62.8	0.382	4.91	84.0	0.375
m 2	4.73	73.2	0.393	4.80	89.8	0.414
7	5.78	64.5	0.308	5.18	73.6	0.391
14	5.53	53.8	0.322	5.16	61.5	0.356
f 2	3.53	96.6	0.432	2.24	140.3	0.472
7	5.22	66.4	0.338	4.09	100.8	0.444
14	5.56	60.8	0.358	4.56	91.6	0.399
Susp.	**	***	**			
Chilling	NS	NS	NS			
Aging	**	***	*			
PS						
2)		64.2)		)	55.3	
7)	6.32	49.1)	0.296	) 6.71	49.4	0.280
14)		50.5)		)	46.1	
Susp.	*	**	NS			
Chilling	NS	NS	NS			
Aging	NS	***	NS			
BF						
	2.95	78.5	0.379			
Susp.	NS	NS	NS			
Chilling	NS	NS	NS			
Aging	NS	NS	NS			

*** <0.1% significant
** <1.0% "
* <5.0% "
NS not significant

s = slow chilling
m = medium "
f = fast "
2, 7, 14 - days aged post mortem

TABLE 3 (cont.)

ST	Tenderstretch			Normal		
	Score	Force (N)	Work (J)	Score	Force (N)	Work (J)
	3.54	82.4	0.419			
Susp.	NS	NS	NS			
Chilling	NS	NS	NS			
Aging	NS	NS	NS			
SM						
2	3.82	79.0		2.57	117.8	
7	4.03	73.9	0.390	3.10	95.7	0.500
14	4.18	70.1		3.16	93.4	
Susp.	***	***	*			
Chilling	NS	NS	NS			
Aging	**	**	NS			
GM						
2		67.1			79.9	
7	5.04	65.0	0.321		67.0	0.361
14		58.0			66.6	
Susp.	NS	*	*			
Chilling	NS	NS	NS			
Aging	NS	*	NS			