Elektrische Stimulierung, Kühlung und folgend Fleischqualität

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Es werden Methoden der elektrischen Stimulierung für Lamm - und Rindfleisch beschrieben im Hinblick auf Voltspannung, Schwingungshäufigkeit, Zeit und nachfolgeude Verarbeitung. Das Endprodukt der Fleischverarbeitung im Neuseeland wird gefroren. Die Gewährleistung von Fleischzartheit hängt natürlicherweise von den Verarbeitungsmethoden ab.

Stimulierungsmethoden für Lammfleisch werden beschrieben die entweder unmittelbar nach dem Schlachtvorgang oder est nach der Zubereitung des Schlachtkörpers angewendet werden können. Ausserdem werden die Behandlung nach der Stimulierung sowie das Gefrieren in Bezug auf die Fleischzartheit diskutört. Für Rindfleisch werden ähnliche Methoden beschrieben.

Electrical stimulation, refrigeration and subsequent meat quality

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The development of electrical stimulation procedures for lamb and beef is discussed with respect to voltages, pulse frequency, timing and subsequent processing. In New Zealand the end-point of processing is the frozen product and this affects the degree to which meat must be conditioned if tenderness is to be maintained.

Systems for the stimulation of lamb either immediately after slaughter or after completion of dressing are described, and the effect of post-stimulation holding and freezing treatments on tenderness discussed.

Similar information is presented for beef carcasses.

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Stimulation électric, refrigeration, et la qualité de la viande résultat

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Le développement des procédé de stimulation électric pour l'agneau et le boeuf est discuté avec la référence à voltages, fréquence, temps et la préparation de la carcasse à suivre. En Nouvelle Zealand la préparation pointe de fin est le produit glacé et ce déterminer combien de muscle pH doit réduire avoir afin de maintenir la tendreté.

Les systèmes sont décrirent pour le stimulation d'agneau ou immédiatement après abattis ou après le fin d'habillage et l'effect de post-stimulation de séjour et treatement glacé sur la tendreté.

Semblable information est presenté pour la carcasse boeuf.

Электростимулирование, охлаждение и качество мяса

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Обсуждается разработка способов электростимулирования туш ягнят и крупного рогатого скота с учетом напряжения тока, частоты импульсов, продолжительности стимулирования и последующей обработки. В Новой Зеландии конечной целью обработки является производство замороженного мяса, что определяет степнень созревания, обеспечивающую необходимую нежность.

Приведено описание систем стимулирования туш ягнят сразу после убоя или после разделки в убойном цехе; указано влияние выдержки после стимулирования, а также замораживания на нежность мяса.

Представлена аналогичная информация относительно туш крупного рогатого скота.

Electrical Stimulation, Refrigeration and Subsequent Meat Quality

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The detrimental effects of early and rapid chilling and/or freezing on the tenderness of lamb and beef are well documented and have been the subject of research in many institutions throughout the world since the discovery of cold shortening in New Zealand in 1963[1]. Thaw shortening as a result of rapid thawing of meat frozen pre-rigor also has detrimental effects on tenderness[2]. The avoidance of cold and thaw shortening by holding carcasses at or above 10°C to ensure complete setting of rigor before chilling and freezing has been employed in New Zealand to produce uniformly tender lamb and beef[3]. The process is known as "Conditioning and Aging" (C & A).

When large numbers of animals are being processed, rapid chilling or freezing may be necessary soon after slaughter unless very large holding areas are available. Under these conditions the majority of carcasses may suffer from cold shortening, and if cooked from the frozen state would also exhibit thaw shortening. The toughness likely to be produced by early freezing is illustrated in the frequency distributions of shear force value for legs and loins from early frozen lambs (Fig. 1). Carcasses which are "conditioned" by holding for 16-24 hours at 10°C to permit rigor setting before being frozen do not suffer from either cold or thaw shortening and are acceptably tender (Fig. 1b). A further 24 hours is required to produce "conditioned and aged" lamb (Fig. 1c). "Conditioned only" meat is considered an acceptable standard for the large majority of markets, with C & A quality being produced for luxury markets.

The realtively long periods required to condition lamb (16-24 hours) have been the spur to study of methods of accelerating rigor in lamb. High temperature holding was one procedure which was tested as a means of reducing conditioning times[4], but was not considered to be a practical method.

Electrical Stimulation of Lamb

Electrical stimulation of muscles reduces the delay phase of rigor and thus shortens conditioning time. The early work on electrical stimulation of lamb in New Zealand[5] employed a 30-minute stimulation period with 230 volts applied 30 minutes after death. Conditioning time was reduced from 16 hours to 3 hours. Subsequent investigation showed that much shorter stimulation periods with higher voltages applied soon after slaughter reduced conditioning time even further. Lambs stimulated for 45 seconds within 5 minutes of slaughter went into rigor rapidly, with the loin muscle pH being below 6 within an hour of slaughter. The dressed carcasses from stimulated lambs could therefore be moved into the freezer at 1 hour post mortem and frozen without adversely affecting tenderness, provided that the freezing rate was not excessive (Fig. 2). The level of tenderness achieved on cooking from the frozen state was that of a conditioned carcass, but below that achieved by the C & A process. This pre-dressing stimulation system can operate under commercial conditions, but has the limitation that a separate stimulation facility is required for each dressing chain. Stimulation post dressing could be conducted with one facility for the entire production. Complete dressing, weighing and inspection requires approximately 25 minutes, so carcasses can be stimulated no earlier than 30 minutes post mortem. This delay is a disadvantage since muscles are beginning to cool, nerves are becoming anoxic, and therefore longer stimulation periods are needed. The tenderness of loins from carcasses stimulated for 1-5 minutes 30 minutes post mortem is shown in Table 1. A two-minute stimulation period was needed to ensure "conditioned" level tenderness in the carcasses frozen 90 minutes after stimulation. Stimulation of carcasses more than 30 minutes after death showed effectiveness decreasing with time (Table 2), although longer stimulation times may offset the decrease.

Table 1
Effect of duration of stimulation on pH fall and tenderness of longissimus muscles in lamb carcasses stimulated 30 min PM. Lambs into freezer 2 h PM. Loins roasted from frozen state.

Duration of Stimulation (minutes)	LD pH 2 h PM	LD Tenderness (Mean ± standard deviation)
0	6.85	77 ± 26
1	6.19	48 ± 23
2	5.98	31 ± 4
5	5.93	36 ± 6

Table 2
Effect of prestimulation delay on pH fall and tenderness of longissimus muscles of carcasses stimulated for 2 minutes. Carcasses into freezer 2 h after stimulation. Loins roasted from frozen state.

Prestimulation delay (minutes)	LD pH 2 h PM	LD Tenderness (Mean ± standard deviation)
25	5.98	32 ± 13
35	6.26	37 ± 6
45	6.61	51 ± 14
90	6.65	71 ± 12
Unstimulated	6.85	77 ± 26

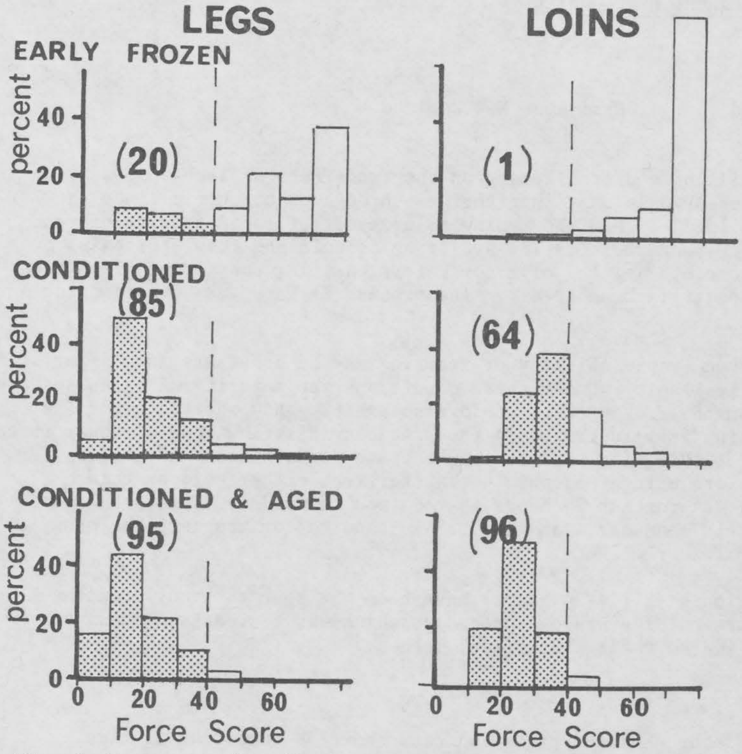

Fig. 1 Frequency distribution of shear force values for legs and loins from early frozen, conditioned, and conditioned and aged lambs roasted from the frozen state. The figure in parenthesis shows the percentage of shear force values less than FS 40 on the arbitrary scale of the MIRINZ tenderometer. A force score of 40 is considered to be the limit of acceptability.

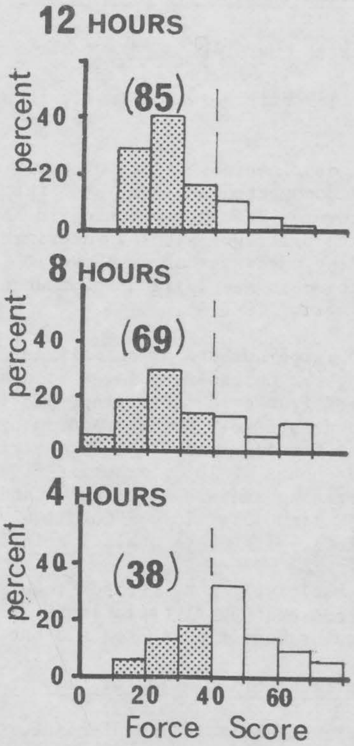

Fig. 2 Frequency distribution of shear force values for legs of stimulated lambs frozen at different rates and later roasted from the frozen state. Figure in parenthesis shows the percentage of values less than FS 40 (shaded portion)

A pulsed wave form was employed for earlier trials[6,7], but the parameters used were empirically derived. Subsequent experiments showed that for beef neck muscles the greatest fall in muscle pH during stimulation occurred with pulse frequencies between 5 and 16 per second[8] (Fig. 3). The efficacy of the selected pulse frequency has been shown by comparison of tenderness of lambs stimulated with 50 Hz and 14.28 pulses per second at 800 volts. With 50 Hz at 800 volts, lamb carcasses could only be stimulated for half of the desired 90-second stimulation period before the tendons in the hocks melted, dropping the carcass on the floor. These carcasses, if moved into a freezer two hours later and then frozen, gave legs and loins which were relatively tough, whereas legs and loins from carcasses stimulated with the pulsed current for the full 90 seconds and frozen similarly were acceptably tender. The voltage employed also exerts a significant effect on the level of tenderness achieved, especially in the legs. With 400 volt pulses, only the loins reached the desired tenderness, whereas with 800 volt pulses, both legs and loins were acceptably tender (Fig. 4).

After either pre-dressing or post-dressing stimulation of lamb, a short holding period is required to permit glycolysis to proceed sufficiently so that cold shortening will be avoided when the muscle temperature is dropped below 10°C. A moderate freezing rate then ensures that adenosine triphosphate is virtually destroyed before freezing occurs, avoiding the possibility of thaw shortening on cooking. If rapid freezing rates are to be used, more complete conditioning is required before freezer entry. Both pre- and post-dressing stimulation processes used in New Zealand are tailored to permit commencement of freezing 1½ hours after stimulation, provided that the deep leg temperature does not fall below -4°C in less than 12 hours from freezer entry. Extended delays before commencement of freezing enable faster freezing rates to be utilized without impairment of quality. The tenderness likely to be achieved with a variety of delays and freezing rates can be judged from the total time from slaughter until the deep leg temperature reaches -4°C (Fig. 5). A two-hour delay followed by 12 hours for the deep leg to reach -4°C gives virtually the same tenderness as a six-hour delay and 8 hours to -4°C. This gives plant designers and operators a measure of flexibility in determining how they achieve the required level of tenderness. If a "conditioned and aged" level of tenderness is desired, the stimulated carcasses can be held for 10 hours at 6°C, then a further 12 hours taken for the deep leg to reach -4°C. This is a significant reduction from the 40 hours at 10°C, plus freezing time, required without stimulation.

Electrical stimulation of lamb either pre- or post-dressing is a commercially attractive process to ensure acceptable levels of tenderness in frozen lamb which may be cooked from the frozen state. Cooking from the frozen state will give the worst result with regard to tenderness because both cold and thaw shortening effects are exposed. If the meat is to be cooked after a slow thaw, the margin between stimulated and non-stimulated meat is reduced, since the thaw shortening effect is eliminated.

Stimulation has an important role even with chilled meat, which is highly vulnerable to cold shortening[9]. As well as considerable benefit to tenderness, it may reduce microbiological problems by permitting rapid chilling and thus increase shelf life.

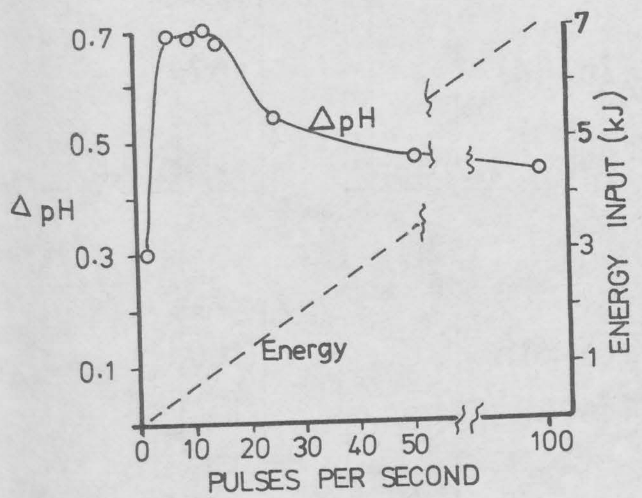

Fig. 3 Effect of pulse frequency on pH fall during stimulation (ΔpH) of beef sternomandibularis muscles with 200 volt pulses for 120 seconds.

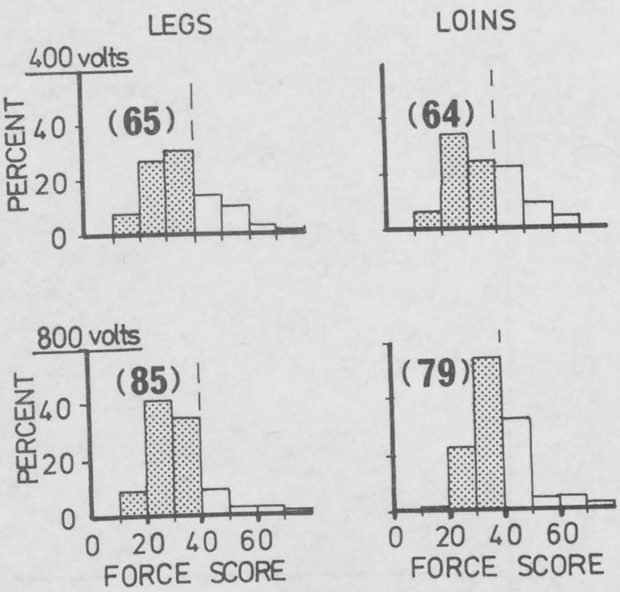

Fig. 4 Frequency distribution of shear force values for legs and loins from carcasses stimulated 30 minutes post mortem with 400 or 800 volt pulses at 14.38 pulses per second. Carcasses frozen 2 hours post stimulation and cuts roasted from the frozen state.

Electrical Stimulation of Beef

Beef processing presents a slightly different picture due to the larger size of the animal and differences in rates of conditioning and aging.

Conditioning of beef requires some 21 hours chilling at a slow rate to ensure that cold shortening and thaw shortening through boning out and freezing too soon are to be avoided[10]. The tenderness of "conditioned only" beef is similar to that of "conditioned only" lamb loins. A degree of aging is required to produce acceptably tender beef. A recommendation for C & A beef is 66 hours at 10°C from end of chilling to start of freezing. High quality beef can be produced in 4 days and can then be frozen without detracting from this quality.

Electrical stimulation of beef, first employed by Harsham & Deatherage[11] as a means of reducing the time required to age, has received considerable attention since it enables tender meat to be produced even with rapid chilling. In New Zealand emphasis has initially been on stimulation of beef sides 30 minutes after slaughter. This enables direct comparison of unstimulated and stimulated cuts or muscles. The voltages and pulse frequencies employed have been the same as those used for lamb. Various processing alternatives have been considered after stimulation. It is envisaged that the stimulated beef could be chilled rapidly and boned out either 5 or 24 hours post mortem. Alternatively, the stimulated beef may be hot-boned, packaged and then aged before freezing[12].

Beef chilled rapidly soon after slaughter is tough unless stimulated before chilling[13]. Even if stimulated, the rapidly chilled beef is "conditioned only" quality, but has an advantage over the non-stimulated, rapidly chilled beef in that it will age to give highly acceptable meat, whereas the non-stimulated meat is tough even after aging (Fig. 6). Hot-boning after stimulation produces cuts which, with the exception of the fillet, are more tender than non-stimulated cuts. The fillet toughens slightly as a result of its removal from the carcass, not as a result of stimulation. Aging the cuts in the carton occurs more rapidly after stimulation, since the rapid rigor means that aging commences at a higher temperature.

Conclusions

Electrical stimulation of lamb or beef has its main value in hastening rigor onset, so that even with rapid chilling or freezing, cold shortening is avoided, thereby ensuring a reasonably tender product which can be aged further if desired. In countries without refrigeration the value of electrical stimulation would be minimal. At the other end of the scale the benefits are dramatic, the extreme situation applying in New Zealand and Australia, where small carcasses are subjected to early blast freezing (and blast chilling in the process). But in the great majority of countries where efficient chilling without freezing is the norm, the benefits of electrical stimulation are still substantial for both lamb and beef.

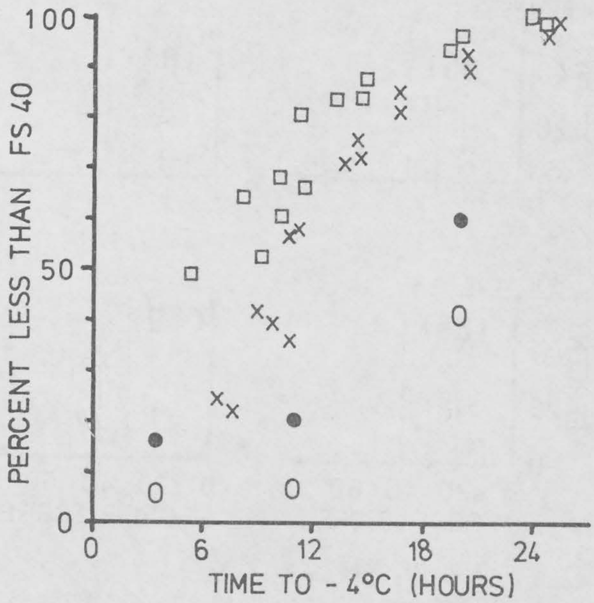

Fig. 5 Relationship between percentage of SF values less than 40 and time from slaughter to reach -4°C deep leg.
Stimulated loins X; legs □
Non-stimulated legs ● ; legs 0
Conditioned only quality is not less than 65% of values below 40 for loins and 85% for legs.

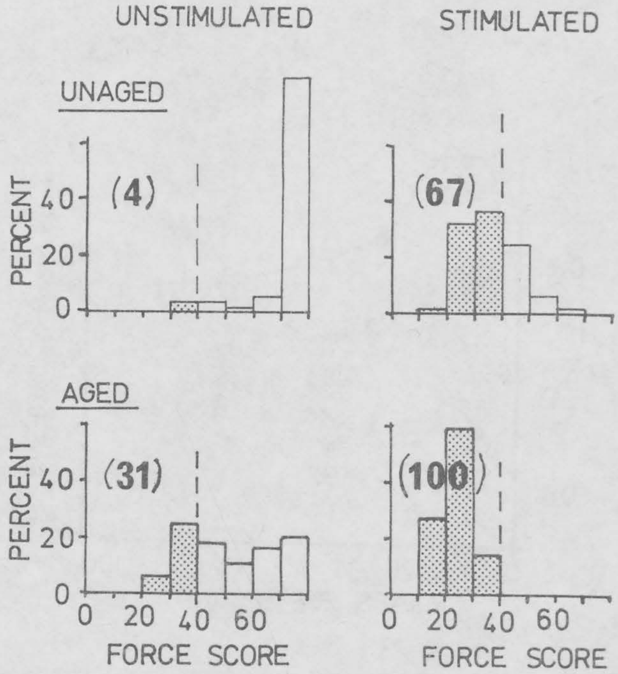

Fig. 6 Frequency distribution of shear force values for grilled longissimus muscles from rapidly chilled, unstimulated and stimulated beef sides. The unaged cuts were frozen 24 hours post mortem. The aged cuts were held at 10°C for 66 hours before freezing.

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Hat die elektrische Stimulation, ausser der Verhinderung der "cold shortening" also einen günstigen Einfluss auf die Zartheit des Fleisches ?

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Es ist bekannt, dass die elektrische Stimulation der Schlachtkörper sofort nach dem Schlachten und Herrichten und bevor der Kühlung, die Zartheit des erwärmten Fleisches beträchtlich erhöht. Diese Erhöhung wurde, wie gezeigt durch die Anwesenheit längerer Sarkomeren in den Muskeln von stimulierten Schlachtkörperhälften im Vergleich mit nicht stimulierten hälften, der Verhinderung von "cold shortening" zugeschrieben. Eine vorhergehende Untersuchung zu dem Zweck die Möglichkeit eines Zartheitseffekts bei elektrischer Stimulation in der Abwesenheit einer Schnellabkühlung nachzuprüfen, ist durchgeführt worden. Vier Bullen (Tiere 309, 310, 313 und 314) wurden geschlachtet, in Schlachtkörperhälfte zerlegt und eine Hälfte von jeder Tier wurde elektrisch stimuliert (110 V; 0,1 - 0,6 Amp. für 4 min) innerhalb einer Stunde nach der Betäubung. Beide Schlachtkörperhälften sind während 21 h oben 15°C konditioniert und nachher während 24 h gekühlt worden. Die elektrische Stimulation bewirkt bei jedem der 4 Tiere eine bedeutende Erniedrigung des pH, trotzdem die Kontrollschlachtkörperhälften eine erhebliche Verschiedenheit zeigten. Die Länge der Sarkomeren und die Warner-Bratzler Scherwerte sind bestimmt worden auf Longissimus und Latissimus Muskeln (4 Tiere x 2 Muskeln = 8 Proben). Die Scherwerte waren in 4 Proben, bei elektrischer Stimulation, erheblich erniedrigt (Latissimus bei Tiere 310 und 314, Longissimus bei Tiere 309 und 314) obgleich in 1 Probe eine wesentlich höherer Wert bekommen wurde (Longissimus Tier 313). Nur in 2 Fällen (Latissimus Tier 314, Longissimus Tier 309) war eine bedeutende parallele Zunahme in der Länge der Sarkomeren notiert, weil in 1 Probe die Länge der Sarkomeren, bei Stimulation, bedeutend erniedrigt war (Latissimus Tier 313). Die Abweichende Ergebnisse ermittelt bei Tier 313 können eine schnelle Abfall des pH in der Kontrollschlachtkörperhälfte zugeschrieben werden. Ungeachtet der Feststellung einer erheblichen Verschiedenheit, suggerieren diese Ergebnisse, dass elektrische Stimulation in der Lage sein kann, ein Zartheitseffekt auf Rindfleisch auszuüben, völlig ausser der Verhinderung der "cold shortening" und unabhängig von den Variationen in der Länge der Sarkomeren.

Does electrical stimulation increase beef tenderness apart from the prevention of cold shortening ?

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It is well known that low voltage electrical stimulation of beef carcasses immediately after slaughtering and dressing and before chilling significantly increases cooked meat tenderness. This increase has been attributed to the prevention of "cold shortening" as indicated by the presence of longer sarcomers in muscles from stimulated carcass sides when compared to non-stimulated sides. A preliminary experiment was carried out to investigate the possibility of a tenderizing effect of electrical stimulation in the absence of rapid chilling. Four bulls (animals 309, 310, 313 and 314) were slaughtered, split into sides and one side from each carcass was electrically stimulated (110 V; 0.1 - 0.6 Amps for 4 min) within 1 h after stunning. Both sides were kept for 22 h at ca. 15°C and then chilled for 24 h. In all 4 animals, electrical stimulation significantly increased rate of pH-decline, although values for control sides showed considerable variation.

Sarcomere lengths and Warner-Bratzler shear values on longissimus and latissimus samples were determined (4 animals x 2 muscles = 8 samples). In 4 samples shear values were significantly lowered by electrical stimulation (latissimus in animals 310 and 314, longissimus in animals 309 and 314), in 1 sample however a significantly higher value was obtained (longissimus animal 313).

In 2 samples only (latissimus animal 314, longissimus animal 309) a concomittat significant increase in sarcomere length was noted, whereas in 1 sample sarcomere length was significantly decreased by stimulation (latissimus 313). Aberrant results obtained with animal 313 may be related to a high rate of pH decline in the control side. The results although showing considerable discrepancies suggest the possibility that electrical stimulation may have a tenderizing effect in beef muscle, quite apart from the prevention of cold shortening and not related to differences in sarcomere length.

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La stimulation électrique, a-t-elle un effet sur la tendreté de la viande, en dehors de la prévention du cold shortening ?

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Il est connu que la stimulation électrique à basse tension des carcasses de bœuf, immédiatement après l'abattage et le parage et avant le refroidissement, augmente de façon significative la tendreté de la viande chauffée. Cette augmentation a été attributée à la prévention du "cold shortening", comme indiqué par la présence de sarcomères plus longs dans les muscles des demi-carcasses stimulées. On a fait une expérience préliminaire à fin d'investiguer la possibilité d'un effet sur la tendreté de la stimulation électrique dans l'absence d'un refroidissement précoce. Quatre taureaux (animaux 309, 310, 313 et 314) ont été abbatu, séparés en demi-carcasses et chaque demi-carcasse a été stimulée par voie électrique (110 V; 0,1 - 0,6 Amps, 4 min) moins qu'une heure après l'étourdissement. Les deux demi-carcasses étaient conditionnées à ca. 15°C pendant 22 h suivi par 24 h de refroidissement. Dans tous les animaux, la stimulation accélérait la chute de pH, même si les demi-carcasses témoins montraient un variabilité considerable. Des longueurs de sarcomères et des forces de cisaillement (Warner-Bratzler) étaient déterminées sur des échantillons des muscles longissimus d. et latissimus d. (4 animaux x 2 muscles = 8 échantillons). Dans 4 échantillons les forces de cisaillement étaient abaissées significativement par stimulation électrique (latissimus animaux 310 et 314, longissimus animaux 309 et 314). Dans un échantillon néanmoins une valeur significativement plus haute était obtenue (longissimus animal 313). Dans 2 cas seulement (latissimus animal 314; longissimus animal 309) un accroît parallel dans la longueur des sarcomères était noté, tandis que dans un échantillon la longueur des sarcomères était abaissée significativement par stimulation (latissimus animal 313). Les résultats obtenus avec l'animal 313 pourraient être liés à la chute de pH intensifiée dans la demi-carcasse témoin. Malgré la grande variabilité observée, les résultats suggèrent la possibilité d'un effet attendrissant de la stimulation électrique en dehors d'une prévention du "cold shortening" et pas lié à la longueur des sarcomères.