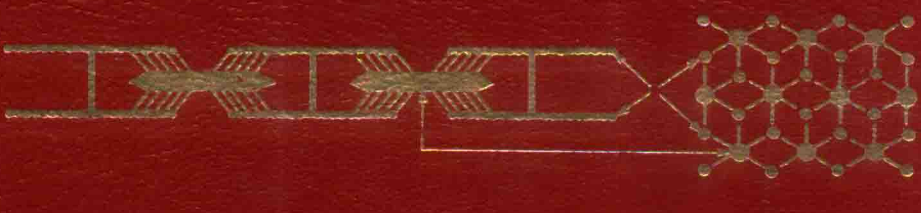
# Advances in Meat Research

## Volume 1

## Electrical Stimulation



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## Electrical Stimulation

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# Preface

The *Advances in Meat Research* series has arisen from a perceived need for a comprehensive coverage of certain topics that are pertinent to meat and meat products. We, the editors, have made the decision to concentrate on a series of related topics that are deemed to be important to an understanding of meat, both fresh and processed. It is our sincere hope that by focusing upon areas related to meat science that researchers who contribute to this volume can not only update those involved in academia and industry but also promulgate facts that may lead to solutions of meat industry problems and aid in improving the efficiency of various associated industrial processes.

We have chosen to devote *Volume 1* to electrical stimulation in view of the widespread interest in its meat industry applications. Although the classical study by A. Harsham and Fred Deatherage was published in 1951, it was not accepted by the meat industry owing to a number of factors that are discussed in the text. These investigators did, however, lay the groundwork for modern electrical stimulation of carcasses by their detailed studies on the effects of varying current, voltage, frequency, wave forms, and time. The basic information provided by these workers saved a great amount of experimentation by those who subsequently "rediscovered" electrical stimulation.

Another important study that played a key role in the development of electrical stimulation was the simple observation of R. H. Locker, published in 1960, showing that muscle shortening was related to meat tenderness. This study proved to be the basis for the discovery of cold shortening by Locker and Hagyard in 1963, which led to recognition of the need for speeding up glycolysis to prevent cold shortening in lamb carcasses that were frozen in the prerigor state for export to North American markets from New Zealand.

W. A. Carse, also, at the Meat Industry Research Institute of New Zealand (MIRINZ) published the third landmark paper in 1973 that led others to study electrical stimulation. This was the first study to demonstrate that electrical stimulation accelerated glycolysis and could be used to prevent cold shortening in prerigor meat. This report proved to be the stimulus for all subsequent investigations on electrical stimulation as a means of improving meat quality, and its importance is attested to by the frequency with which it is cited in the voluminous literature on this important subject.

Finally, to put the historical aspects of this subject into perspective, we wish to acknowledge the contribution of B. B. Marsh, formerly of the Meat Industry Research Institute of New Zealand and now of the University of Wisconsin, who, without any prior knowledge of the early work of Harsham and Deatherage, theorized that electrical stimulation might be useful in speeding up glycolysis and thus in preventing cold shortening. He was responsible for stimulating W. A. Carse to initiate his most important investigation. As a final note, one of the editors (A. M. Pearson) publicly acknowledges having delayed Mr. Carse in this most important study while he worked on less promising methods for speeding up glycolysis during the co-editors' stay at MIRINZ in 1971–1972.

A. M. Pearson
T. R. Dutson

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# Contents

# 1

# Cold-induced Toughness of Meat

*R. H. Locker*[1]



Before 1960, ideas about meat tenderness tended to be dominated by the role of connective tissue, of which the quantity, quality, and arrangement were held to be important (Ramsbottom *et al.* 1945). There is still no reason to doubt this judgment. The improvement in tenderness on aging, without much apparent change in the connective tissue, might perhaps have been expected to direct more attention to the myofibrillar component. However, in the late 1950s, the time was only just ripe for serious study of the myofibril. Acceptance of the sliding filament theory of muscular contraction was a recent event in muscle biology. The power of electron microscopy was making an impact in that field but had barely touched meat science. However, it was not so much these exciting developments that led to a new interest in the myofibrillar contribution to toughness, but a much more mundane observation.

In 1958, I was trying to demonstrate proteolysis during the aging process and having little success. In the course of the work, I examined, by phase contrast microscopy, homogenates from a wide range of beef muscles, which had gone into rigor on the carcass under normal abattoir condi-

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tions. I was struck by the wide range of sarcomere lengths within and between muscles (Locker 1959). Could this be a factor in meat tenderness, and if so, why had not someone considered it before? Some simple experiments on psoas muscle (in which the contribution of connective tissue is minimal) showed that shortening induced by excision or partial excision after dressing led to pronounced toughening (Locker 1960). Not long afterward, again as a chance observation in work directed to another purpose, I found that excised beef muscles shortened markedly when allowed to go into rigor at 2°C (Locker and Hagyard 1963). These latter two papers, based on quite primitive experiments, were published with hesitation and with the nagging doubt that surely someone must have published such easily observable facts before. Curiously, it seems that it was not so. The two papers have in the long run far exceeded their writer's original estimate of their worth. Taken together, they have opened up a new field in meat science: the relationship of tenderness, contraction, and cold, and have led to a new emphasis on the role of the myofibril.

For this laboratory, then in its formative years, these findings could not have come at a more opportune time. They proved immediately relevant to the first technical challenge offered by industry: the solution of a toughness problem of national significance to our frozen lamb trade. Solving this problem set the course of research here for the next decade and even to the present. Exploring the effects of rigor temperature on contraction state and tenderness was undertaken with vigor by other workers at this institute simultaneously with the search for a practical solution. This has only now reached a satisfactory conclusion in the technique of accelerated conditioning by electrical stimulation. In that period, cold shortening has become a matter of interest to research centers and meat industries in many other places.

## A SAD STORY: NEW TECHNOLOGY MEANT POORER QUALITY

Mechanical refrigeration made its first impact on international meat trading in the transatlantic run and soon extended to Australia. New Zealand was not far behind; in fact, 1982 marks the centenary of the first shipment of frozen mutton to London in the sailing ship *Dunedin*. For a young colony with limited resources, it was a godsend. Where previously only the durable products of animal husbandry such as wool, hides, and tallow had been exportable, the carcass had suddenly acquired a value in the receptive markets of industrial Britain. Over a century, the frozen meat trade increased in volume until it became, as it remains, our largest earner of overseas funds. In this trade, lamb still dominates as the meat animal ideally suited to a grassland economy. Conveniently, it harvests the annual flush of pasture without the need for wintering over. Although not the largest producer, New Zealand is the largest exporter of lamb, and by reason of its distance from the market, the carcasses travel almost exclusively in frozen form.

The end of the second world war saw a rapid increase in production, due largely to the development of aerial topdressing of hill country with superphosphate. In the freezing works (packinghouses), the old freezers soon became inadequate for the swollen throughput (usually more than 10,000 head per day and in some works more than 20,000). The old freezers were steadily replaced by new blast freezers. The old technology involved hanging lambs overnight on a ventilated cooling floor to reduce the heat and moisture load on the freezers, to which they were consigned next morning. Carcasses were then frozen slowly beneath grids of brine pipes. The new technology meant that lamb carcasses, sometimes straight from the scales, and never more than a few hours postmortem, were subjected to rapid freezing. The new situation was therefore an extreme one, where small carcasses were subjected to powerful blasts of very cold air, resulting in abnormally high rates of chilling and freezing. Since it is generally true that quick freezing is best for foods, it might have been expected that quality would have improved. Quite the reverse occurred.

About 1960, complaints from Britain of toughness in New Zealand lamb became sufficiently persistent to cause the New Zealand Meat Producers' Board to call for a scientific assessment. It was expected that this would rebut such claims and reestablish our good reputation. However, the very first experiment showed the complaints to be justified and implicated the new freezing technology. Lambs processed in the pre-war manner were found to be invariably tender, while blast-frozen lambs could be tender or very tough or anywhere in between. It became obvious at this point that the observations described in the introduction to this chapter were likely to provide an explanation, and intense study began along these lines. Not long afterward, our small but growing exports to the United States met with resistance for the same reasons, and a solution became urgent. At the time, the only solution seemed to be to hold the carcasses before entry to the freezer. Here freezing works found themselves in a dilemma because most of the cooling floors had vanished. Deemed no longer necessary, they had provided the most obvious space to build the new blast freezers. So the search for alternative solutions began, and that story will be part of the substance of this chapter.

## THE RELATIONSHIP BETWEEN CONTRACTION AND TOUGHNESS

The original paper on this relationship (Locker 1960) was based on rather primitive experiments and failed to show its true subtlety. This was revealed by the work of Marsh and Leet (1966A,B) using the cold effect to set beef neck muscles at different lengths, followed by shearing of the cooked material. The curve relating shear force to shortening (Fig. 1.1) showed distinct phases. Toughness scarcely increased in the contraction range of 0–20%, but rose steeply from 20 to 40% and then declined as sharply from 40 to 60%. This relationship has been confirmed on a number of occasions since (Davey *et al.* 1967, 1976).

The dramatic decrease in toughness with extreme shortening is at first sight surprising, but appears to have a perfectly adequate explanation. Micrographs show that such severe contractions are not uniform. Intense nodes of contraction alternate with zones which are stretched and torn (Marsh *et al.* 1974). The muscle has in fact tenderized itself by tearing up its own structure. The tissue may be regarded as a mixture of toughened and self-tenderized fibers, the latter becoming progressively more important as shortening increases. This region of the curve is not normally

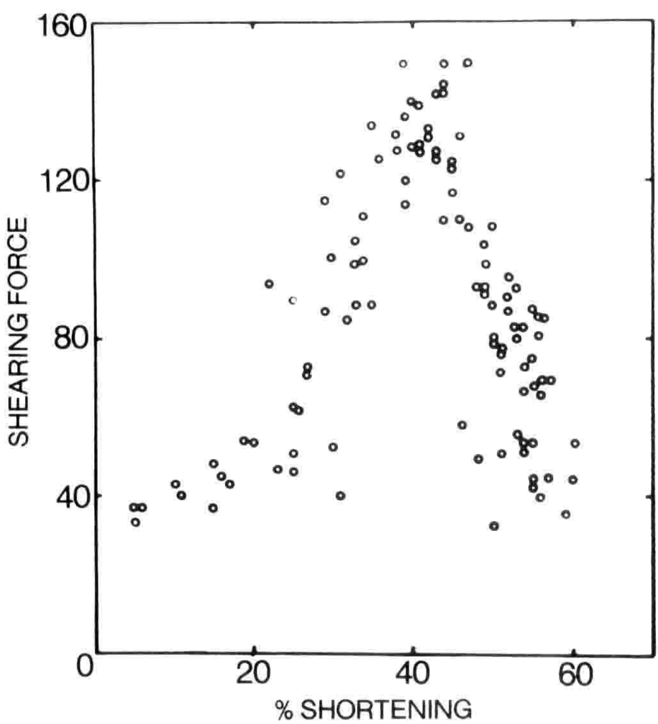


FIG. 1.1. Relative tenderness in relation to the shortening induced by transfer of samples from room temperature to 2°C at intervals during rigor onset. Cold shortening as percentage initial excised length.
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