

This Week's Citation Classic™

Marsh B B & Leet N G. Studies in meat tenderness. III. The effects of cold shortening on tenderness. *J. Food Sci.* 31:450-9, 1966.

[Meat Industry Research Institute of New Zealand, Hamilton, New Zealand]

Cold shortening strongly affects meat tenderness. As shortening increases from 20 to 40 percent of initial muscle length, a several-fold toughening occurs; it is reversed (by tissue rupture) with further shortening. Maintenance of musculoskeletal attachments does not necessarily prevent localized shortening and toughening. [The SCJ® indicates that this paper has been cited in over 145 publications since 1966, making it the most-cited paper published in this journal to date.]

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"Frozen lamb has long provided much of New Zealand's export earnings, so complaints of toughness were taken very seriously when strongly expressed by overseas buyers in 1961. The meat industry turned to the young and still small Meat Industry Research Institute for help, and a major study of the problem was initiated. The trouble was soon traced to two recent changes in packinghouse practice: the installation of blast freezers and the elimination of a previously imposed delay of several hours before carcasses entered the freezers. Separately, these modifications were shown to be without effect; together, they could (and frequently did) convert the normally tender meat into a virtually inedible product.

"After fruitless efforts to explain the toughening in terms of a lack of aging, we realized that the observations were precisely what would be expected if two recent institute discoveries—shortening-induced toughening¹ and cold-induced shortening^{2,3}—were operating in the *in situ* musculature during rapid, early postmortem cooling. But many questions arose: could cold shortening produce a great enough toughening to ex-

plain the strong consumer response? Would skeletal restraint prevent the length change? To answer these and many other queries, a secondary project, later appearing as 'Studies in meat tenderness, III,' was begun, using bovine sternomandibularis ('neck') muscles to facilitate measurements of length and tenderness and to allow more controllable, precise, and rapid temperature changes to be made.

"In relation to our concurrent lamb carcass studies, the investigation showed that cold shortening certainly could produce a massive toughening: more than enough, indeed, to account for the vigorous market reaction. It also established that maintained skeletal attachment did not necessarily prevent large localized changes in length and toughness, and validated the delay-before-freezing procedure we had devised empirically. Later, it led to an observation of rather greater significance, for during a 1970 follow-up to the investigation, Bill Carse and I commenced a study of the effects of carcass electrical stimulation on glycolytic rate and cold shortening (reported by Carse⁴). Outside New Zealand, however, nothing was known of these background matters, or of the real reason for the institute's interest in tenderness; the industry refused to permit any mention of its toughness difficulties in our publications, lest an acknowledgment of the problem's existence might depress overseas lamb sales.

"For this reason, I am surprised that the paper has received so much attention, since, deprived of its clear and immediate warning to the meat industries of other countries, the report must have appeared as little more than a confirmation and extension of earlier institute observations. Perhaps the frequent citation is due to the relative order it brought to a rather chaotic scene, demonstrating that a somewhat tidier tenderness pattern emerged when shortening was taken into account. Toughness occurrence, henceforth, was a little less unpredictable.

"Cold shortening and its toughening consequences have not been reviewed in depth for some years, but will be discussed in several chapters of a forthcoming book."⁵

1. Locker R H. Degree of muscular contraction as a factor in tenderness of beef. *Food Res.* 25:304-7, 1960. (Cited 130 times.)
2. Locker R H & Hagyard C I. A cold shortening effect in beef muscles. *J. Sci. Food Agr.* 14:787-93, 1963.
3. Locker R H. Citation Classic. Commentary on *J. Sci. Food Agr.* 14:787-93, 1963. *Current Contents/Agriculture, Biology & Environmental Sciences* 14(3):16, 17 January 1983.
4. Carse W A. Meat quality and the acceleration of postmortem glycolysis by electrical stimulation. *J. Food Technol.* 8:163-6, 1973.
5. Pearson A M & Dutson T R, eds. *Advances in meat science. I. Electrical stimulation.* Westport, CT: AVI Publishers. To be published, 1984.