Delayed Chilling of Lamb — A Review

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ABSTRACT

Shortening of muscles by cold shock, enzymatic action, or both is a major cause of reduced meat tenderness. While chilling and enzymatic actions are highly correlated to tenderness, electrical stimulation and fatness are other factors which influence the tenderness. Emphasis on safety in foods has led to the belief that meat should be cooled as quickly as possible after death. However, evidence to be considered in this review shows that this practice of immediate chilling is in direct opposition to tenderness in lamb. Instead, delay in chilling improves tenderness by influencing factors such as enzyme activity.

Although refrigeration technology has been studied for many years, it is only recently that we have begun to understand the relationship between meat tenderness and chilling rates. These conditions require a considerable amount of knowledge in the area of refrigerant technology. Correspondingly, data suggest that CO$_2$ chilling and associated packaging systems can be used to facilitate shipment and storage for 11 days without significantly affecting freshness, consumer acceptance, odor and palatability (16). Also, a study on chilling of lamb carcasses in liquid N-cooled chambers indicated no adverse effects of liquid N chilling on quality (1).

An important aspect of the process, to which much research effort has been directed, is examination of pre-rigor muscle chilling and its relationship to tenderness. Locker (8) concluded that there was a relationship between postmortem shortening and tenderness. This relationship has been the subject of several investigations in the past decade (11,19). Postmortem shortening is dependent on temperature, but not all muscles show the same temperature-dependence (13). Other studies attributed a part of the increase in tenderness associated with the use of elevated chilling temperatures to increases in autolytic enzyme activity as well as to reduction of cold shortening (12).

Consumer reaction to frozen meat could be determined by its general appearance, but its lack of uniform tenderness seems to be of greatest significance.

CHILLING, COLD SHORTENING AND TENDERNESS

Rapid chilling reduces both weight loss and bacterial contamination, but if applied to pre-rigor meat "cold shortening" of muscle tissues may occur, leading to reduced tenderness. It has been shown that with lamb and mutton carcasses, "processing toughness" can be avoided if chilling is not below 10°C until rigor mortis is completed, which requires 16-24 h. However, this slow chilling introduces problems of microbial growth if the surface is too moist, and excessive weight loss unless the environment has a low drying effect. It has been found possible to achieve a satisfactory combination of conditions to avoid microbial growth or weight loss by careful control of air temperature, relative humidity (RH) and velocity (5).

Taylor et al. (18) reported that lamb carcasses, which were chilled rapidly and slowly (delayed) under controlled conditions. Sensory and objective measurements of tenderness (after cooling and conditioning at 0°C) showed that it was in all instances significantly improved by conditioning, but the rapidly chilled samples remained undesirably tough. The toughening of lamb meat induced by rapid chilling was prevented in carcasses given a pre-slaughter injection of papain solution at the normal commercial dose level of 18 mg/kg (15).

When boned-out cuts of meat are rapidly frozen while still in a pre-rigor state, massive contracture takes place with excessive loss of fluid of the meat subsequently thawed. Rapid chilling of strips of pre-rigor meat to below 10°C leads to unexpectedly rapid glycolysis and pH fall, contraction of up to 60% of the slack length (which is a "cold shortening" phenomenon) and extreme toughening (9).

Taylor et al. (18) reported that lamb is particularly vulnerable and because of its small carcass, it can undergo rapid temperature changes (Fig. 1). They showed (shear comparison and panel tests) that: (a) rapidly chilled meat had higher values of toughening...
than did the slowly chilled samples; (b) MgSO₄-treated rapidly chilled samples had significantly higher values than the control ones, whereas in the slowly chilled samples MgSO₄ had no significant effect; (c) panel scores for texture indication also showed a marked toughening for the rapid chilling, whereas conditioning resulted in an increase of tenderness in both MgSO₄-treated and control groups.

Results of Taylor and his colleagues clearly confirm the earlier observation of New Zealand workers that the toughening effect of cold-shortening in lamb muscle is commercially important when rapid freezing is employed. In comparison, all slowly cooled samples were tender initially and more tender under conditioning. Histological examinations showed that rapidly chilled shortened muscles contained a number of straight, highly contracted fibers while in the slowly chilled muscles the fibers were straight with long sarcomeres.

With advances in meat science it became possible to consider alternative methods of avoiding cold shortening. One method which is particularly interesting is high voltage carcass stimulation immediately after the death of the animal. This method had also been used to accelerate aging of beef by Harsham and Deethage in 1951 (3) and to increase acceptance of frozen meat (4). The reasonable conclusion is that stimulation speeds glycolysis throughout the muscles of beef carcasses, as shown by the rapid pH fall, and that rigor is reached well before temperatures have fallen to levels inducing cold shortening (4).

In the meat packing industry, solidified CO₂ has been used for a number of years as a chilling medium. More recently, CO₂ snow and pellets have been used to facilitate chilling and to retard deteriorative changes during shipment of beef wholesale cuts and lamb carcasses. Lamb carcasses as well as beef wholesale cuts are being chilled with CO₂ pellets for shipment from packers to the retail market with claims of (a) reduced shrinkage, (b) improved appearances, (c) retarded bacterial growth, and (d) longer shelf life.

**CHILLING, ENZYMES AND TENDERNESS**

Proteolytic enzymes of plant origin have been used to tenderize meat since ancient times, but such products are now patented and under industry control. Kang and Rice (6) reported that the enzymatic action takes place in the meat only as the temperature rises during cooking and is halted as the enzyme is inactivated by further heating.

Rhodes and Dransfield (15), working with low and high dosage of enzyme (papain) preparation, used four groups, which were injected with substitute protein and then were slowly chilled. The slow chilling carcasses were delayed at ambient temperatures (appr. 15°C) for 6 h and then chilled at 0°C. For rapid chilling the carcasses were chilled at -2°C with 93% R.H. and transferred to 0°C approximately 6 h later when the temperature reached 5°C in the deepest part of the leg. Work of Rhodes and Dransfield indicates (Fig. 2): (a) rapid chilling about doubled the toughness values of the longissimus dorsi (LD) in the cuts roasted at 50°C and increased it by half when roasted to 65 or 85°C; (b) toughness values were reduced at all temperatures as the level of enzyme increased; (c) toughening produced by rapid chilling was more than eliminated by the tenderizing effect of the high level of enzyme at 65 and 85°C, while the two effects were about balanced at low level of enzyme at these temperatures; and (d) at 50°C the high level was only just sufficient to restore tenderness to that of the slowly chilled carcasses.

Smith et al. (17) proposed that delayed chilling improves tenderness by increasing enzymatic activity. This is supported by data showing that (a) higher muscle temperatures of the fatter lambs are conducive to greater amounts of autolytic enzyme degradation for longer periods; (b) connective tissues from fatter lambs were softer than those from thinner lambs (14). Although the evidence for more proteolysis in the tissues of the fatter lambs is not conclusive, the theory seems interesting, according to Pearson (14), and has some support. A study...
by Smith et al. (17) proposed that the delay in chilling improves tenderness by increasing enzymatic activity.

**CHILLING, FATNESS AND TENDERNESS**

Newbold and Harris (13) indicated that some changes in the myofibrillar component of muscle during the period of the slaughter and the full development of rigor mortis could influence the tenderness of meat. The amount of muscle shortening decreases as the period between slaughter by pre-rigor chilling at 15-20°C lessens the myofibrillar toughness of lamb (11).

Marsh et al. (10) reported that cooling rate is influenced not only by ambient temperatures, humidity and air velocity, but also by the size of cooling body and the depth of tissue. It also pointed out that mature ewe carcasses sustained greater toughening from early freezing than did lamb carcasses (20). This is possibly because the blocky, thick and fat lamb carcasses cool more slowly than the angular, thin and lean mature ewe carcasses.

Smith et al. (17) showed that fatter animals usually produce meat that is more tender than that of leaner animals. These studies indicate that fatter animals tend to deposit greater quantities of marbling; but research during the last 50 years has not clearly demonstrated the relationship of marbling to tenderness, or the necessity of fat deposits for quality. Marbling might be related to tenderness by the insulatory effect of other fats (subcutaneous) in reducing the severity of cold shortening induced by low temperature chilling (2). Others at Texas A&M University suggested that carcass weight and fatness can affect tenderness by the way of cold shortening.

Smith et al. (17) studying the influence of fat thickness to tenderness, suggested that subcutaneous or intramuscular fat could affect the tenderness of muscles by insulating the muscle fibers during post-mortem chilling (changing the rate of temperature and decreasing the period of cold shortening).

The above study showed that fatter lamb carcasses: (a) chilled more slowly; (b) maintained enzyme degradation for longer periods of time post-mortem; (c) sustained less shortening of the muscle sarcomers; (d) had lower muscle pH values; (e) had softer or less perceptible connective tissue; and (f) were more tender than lamb carcasses with limited fat.

These observations support the hypothesis that deposits of increased quantities of subcutaneous or intramuscular fat increase tenderness via changes in post-mortem chilling rate. In other words, this supports the previous study and suggests that fatness improves tenderness by delaying carcass chilling, in contrast to other studies which have suggested the effect of fatness is solely to prevent muscle shortening.

**CONCLUSION**

This review has shown that the shortening of muscles by (a) cold shock, (b) enzymic action, (c) electrical stimulation, and (d) physical effect of fatness are some of the causes of reduced meat tenderness. Thus, extensive investigations will be required to prove whether or not the effect of fatness is strictly a physical one by preventing cold-shortening or also involves proteolysis and breakdown of the connective tissues due to a slower rate of cooling.

Since chilling and enzymatic actions are highly correlated to tenderness, meat packers using unsuitable processing methods can impair the tenderness of meat. Consideration therefore must be given not only to the requirements of the processors but also to the demand of the consumers for tender meat quality in relation to safety.

**REFERENCES**

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DFISA Elects Bjorgen, Nesbitt to Top Posts

Ralph L. Bjorgen, director of international sales, plastics and synthetics division, Norton Co., Akron, Ohio, was elected president of Dairy and Food Industries Supply Association at its 59th Annual Meeting at Palm Springs, April 17-19, 1978.

Arthur W. Nesbitt, President and chief executive officer, Nasco International, Fort Atkinson, Wis., was elected president-elect.

Bjorgen succeeds Duane Poulterer, chairman of the board, Germantown Manufacturing Co., Broomall, Pa., who served since 1976.

Bjorgen has been affiliated with the Norton Co. in marketing and sales since 1950. He was promoted to his present post in 1977 from director of sales.

Norton Company is a diversified industrial manufacturer with 1977 sales of $848 million putting Norton number 272 on the "Fortune 500" list. It has more than 23,000 employees with 112 plant locations in 27 countries. Norton is the leading producer of abrasives and largest maker of diamond drilling and coring bits for the oil and gas exploration industries.

Norton's Plastics & Synthetics Division is one of the leading manufacturers of plastic materials. It is best known as the manufacturer of TYGON(R) Plastic Tubing, and markets to the food, dairy and beverage processing industries, the health care industry, industrial and clinical laboratories and general industry. Its TRANSFLOW(R) Tubing is also well known for use with milking machines, milking systems, and milk transport trucks.

Active in DFISA for 22 years, Bjorgen has held a seat on the board of directors since 1972. He served as chairman of the Expo committee and Expo credentials committee. He has been a member of the following committees: executive, employee relations, awards, membership development, marketing, customer relations, food industry liaison and nominating. He has been a member of technical task committees for plastics, cleanability and sanitary fittings.

His industry memberships include the International Association of Milk, Food and Environmental Sanitarians: Sales and Marketing Executives International; Scientific Apparatus Makers Association, and National Association of Plastics Distributors. He has been active in all phases of Boy Scout work and the United Methodist Church of Ravenna, Ohio.

Bjorgen is a native of Rothsay, Minn. He attended Norwich University, the college of business administration, Kent State University, and completed training at the Graduate School of Sales and Marketing, Syracuse University. He lives at 418 Rosedale St., Ravenna, Ohio, with his wife LaVerne.

Nesbitt joined Nasco International in 1959. The company manufactures plastic products for the dairy, food, medical and cosmetic industries and metal fabrications for the Defense Department. It distributes catalogs worldwide to agricultural and educational customers. Prior to joining Nasco, he was secretary-fieldman of the Pennsylvania Holstein Association.

Nesbitt was elected to the DFISA board of directors in 1974. He has served on the following association committees: annual meeting, awards, employee relations, Expo promotion, finance, membership development and nominating.

His affiliations include American Dairy Science Association, Dairy Shrine Club, International Association of Milk, Food and Environmental Sanitarians, Holstein Friesian Association of America, National Speakers Association, and World Dairy Expo. He is a director of the Bank of Fort Atkinson, deacon of the Congregational Church and past president of the Fort Atkinson Kiwanis Club.

He is a native of Enon Valley, Pa., and is a 1950 graduate of Pennsylvania State University in agricultural economics. Nesbitt and his wife Donna and daughter Sandra live at 711 Blackhawk Drive, Fort Atkinson, Wis.

DFISA is the national trade association of companies which manufacture equipment, products, and supplies for or render services to the food, beverage and dairy processing industries. DFISA membership consists of 425 companies located in the U.S. and abroad.