Delayed Chilling of Beef — A Review

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ABSTRACT

Tenderness of beef can be influenced by various factors. Biochemical changes undergone by the components of muscle during the various stages of rigor mortis influence tenderness of the muscle. One of these changes, the "cold shortening" involved in contraction of muscle, has a particularly strong effect on tenderness. Factors such as relative rates of chill and delay-chill, post-mortem drop in pH and cold storage treatments have a tenderizing effect on beef.

Variation in tenderness of meat exists not only between anatomically different muscles but also between corresponding muscles from animals of the same or different species, and is influenced by both pre-slaughter and post-slaughter conditions. A great deal of research has gone into establishing the effects of pre-slaughter factors such as species, breed, age, sex, nutrition, and exercise and of post-slaughter treatments such as aging (i.e., prolonged storage at temperatures above freezing) and freezing.

Structurally, striated muscle can be regarded as being made up of a fibrillar component responsible for contraction and relaxation of the muscle and a connective tissue component which holds the fibers together and attaches the muscle to the skeletal section. It was believed that the quantity and strength of the connective tissue solely determined the toughness of the meat (12). However, changes in the myofibrillar component during the period between slaughter and the full development of rigor mortis can markedly influence the tenderness of the resulting meat.

One of the earliest observations showed that tenderness was influenced by pre-rigor changes. Muscle cut or excised soon after slaughter was tougher when rigor mortis had developed than uncut muscle which had gone into rigor mortis on the bone (17). Another was that meat cooked soon after slaughter was more tender than meat cooked soon after development of rigor mortis (18).

Therefore the objective of this paper is to review the chilling effect on the beef in relation to other factors involved in meat quality.

POST MORTEM SHORTENING

Studies on meat have demonstrated that muscle shortens upon exposure to cold in the pre-rigor state. Such a shortening results in a reduction in tenderness. To avoid the effect of too rapid chilling or "cold-shortening," some studies suggest that the temperature of the carcass must not be lower than 50 F (10 C) during the first 10 h following slaughter. The amount of shortening with ox neck muscle decreases from about 30% at 37 C to 10-15% at 15 C, but increases with further reduction in storage temperature — a phenomenon known as cold-shortening (8).

Marsh and Leet (9) reported that factors affecting tenderness of meat include breed, feeding and management, anatomy, cellular activity, enzymes, chemical changes both analytical and physical, and cooking techniques. Also research has shown that during the first few hours post mortem, components of muscle undergo a series of biochemical changes culminating in rigor mortis, but few reports even mention the temperature at which the experimental material was held during rigor onset, according to Marsh and Leet (9).

There are a few indications, however, that a muscle which has been cut or excised in a pre-rigor condition may be tougher than expected following rigor onset and cooking.

Locker (7) reported that the toughening might be due to a shortening of the muscle during the onset of rigor mortis. This rigor shortening has been studied recently and showed an interesting "cold shortening" phenomenon in which exposure of bovine muscles to near freezing point causes shortening (8).

Wilson et al. (20) obtained evidence favoring a relationship between temperature and shortening and an effect of both on tenderness. He showed that the effect is much greater in the lower (0-15 C) than in the upper (20-43 C) temperature range. In addition, the accelerated aging to be expected at higher temperatures might well
eliminate any toughening produced during rigor onset at an elevated temperature.

Dutson (2) as well as Parrish et al. (I3) and other workers have shown an increase in aging temperature to be associated with more rapid tenderization of the bovine carcass.

In the bovine as well as in the ovine carcass, the "cold shortening" problem has been shown to be more severe in the smaller and leaner carcass which chills at a slower rate (10). In view of the influence postmortem shortening exerts on meat tenderness, delayed chilling of the bovine carcass combined with boning out of muscles before chilling are possible alternatives to reduce "processing toughness" (I9).

CHILLING RATES AND TENDERNESS

Will and Henrickson (19) examined the effect of muscle removal at three delayed chilling periods (3 vs. 48 h, 5 vs. 48 h, and 7 vs. 48 h) and related this to meat tenderness. In their experiments the Warner Bratzler Shear data for three bovine muscles, for the 48-h chill versus 3-, 5-, and 7-h delayed chill boning treatments, are shown in Table 1. On the other hand, preference tests (table 2) conducted with panelists yielded no significant difference between the chilled BF, LD and SM samples and those of the delayed chill process.

<table>
<thead>
<tr>
<th>Process treatment</th>
<th>BF</th>
<th>LD</th>
<th>SM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chill (48 h)</td>
<td>72</td>
<td>6.41</td>
<td>8.89</td>
</tr>
<tr>
<td>Delay chill (3 h)</td>
<td>6.89</td>
<td>72</td>
<td>8.74</td>
</tr>
<tr>
<td>Chill (48 h)</td>
<td>6.01</td>
<td>72</td>
<td>8.62</td>
</tr>
<tr>
<td>Delay chill (5 h)</td>
<td>6.44</td>
<td>72</td>
<td>9.06</td>
</tr>
<tr>
<td>Chill (48 h)</td>
<td>6.17</td>
<td>72</td>
<td>8.99</td>
</tr>
<tr>
<td>Delay chill (7 h)</td>
<td>6.53</td>
<td>72</td>
<td>9.81</td>
</tr>
</tbody>
</table>

TABLE 1. Warner Bratzler shear (kg) measurements of 3.5 and 7 vs. 48-h treatments from biceps femoris (BF), longissimus dorsi (LD) and semimembranosus (SM) muscles.

<table>
<thead>
<tr>
<th>Process treatment</th>
<th>BF</th>
<th>LD</th>
<th>SM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chilled (48 h)</td>
<td>1.58</td>
<td>1.56</td>
<td>1.56</td>
</tr>
<tr>
<td>Delay chilled (3 h)</td>
<td>1.44</td>
<td>1.44</td>
<td>1.44</td>
</tr>
<tr>
<td>Chilled (48 h)</td>
<td>1.54</td>
<td>1.62</td>
<td>1.62</td>
</tr>
<tr>
<td>Delay chilled (5 h)</td>
<td>1.46</td>
<td>1.38</td>
<td>1.38</td>
</tr>
<tr>
<td>Chilled (48 h)</td>
<td>1.38</td>
<td>1.56</td>
<td>1.56</td>
</tr>
<tr>
<td>Delay chilled (7 h)</td>
<td>1.62</td>
<td>1.44</td>
<td>1.44</td>
</tr>
</tbody>
</table>


Objective and subjective data led to the conclusion that no major differences in meat tenderness existed between muscle which was boned at 3-, 5-, and 7-h post-mortem and that allowed to remain on the suspended carcass for 48 h.

Bailey and Cox of the Meat Research Institute in England have studied rates of chilling of beef carcasses of different weights and degrees of fatness in air at different temperatures and velocities (16). They used 200 beef carcasses sides weighing 220-250 lb. and differing in the degree of fatness. Their studies show: (a) chilling times were as much as 40% faster for the leanest carcasses as compared to the fattest carcasses considering 308 lb. wt. at 32 F and 0.5 m/sec; (b) fatter carcasses at all weights suffered less from shrinkage during the chilling process than leaner carcasses; (c) there is little advantage in using air velocities above 1 m/sec; and (d) cold-shortening will occur if the temperature reaches 50 F or less within 10 h of slaughter.

Thus, fatness was shown to slow down the chilling process. Reduction in cooling time can best be obtained by small reduction in air temperature. Conditions must be selected that will avoid chilling faster than that rate necessary to avoid cold-induced toughness.

CONTRACTION AND TENDERNESS

It is known that some relation exists between tenderness in beef and state of contraction of the muscle fibrils (5). The study by Koonz et al. (5) arose from an experiment in which they observed that an excised piece of beef psoas muscle shortened less at 37 C than at 2 C in passing into rigor mortis.

Locker and Hagyard (8) reported that the maximum shortening of 47.7% occurs at 0 C; at 2 C there is little change, but above this there is a very rapid decline with rising temperatures; also the greatest shortening was obtained with muscle of highest initial pH 7.1 (Table 3).

According to Locker and Hagyard (6), the reversibility of the contraction suggests a cold stimulus effect, perhaps related to the response to an electric stimulus, which persists for a similar period. It should be noted that the shortening temperature curve in the Locker-Hagyard experiments differs from the curves of the other experiment. Thus the relation between toughness and contraction suggests that the cold-shortening effect may be of significance in meat processing wherever freshly slaughtered meat is exposed to rapid chilling or freezing.

STORAGE AND TENDERNESS

Studies on tenderness of beef have shown that beef becomes first less and then more tender with cold storage between slaughter and consumption. On the other hand, freezing has been reported to have a tenderizing action on beef by some workers (3), but not by others (15).

<table>
<thead>
<tr>
<th>Process</th>
<th>Delay time at 25 C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 1/2 h</td>
</tr>
<tr>
<td>Shortening at 25 C (%)</td>
<td>3</td>
</tr>
<tr>
<td>Shortening at 2 C (%)</td>
<td>45</td>
</tr>
<tr>
<td>pH at time of chilling</td>
<td>7.1</td>
</tr>
</tbody>
</table>

Paul and Bratzler (14) used eight pairs of longissimus dorsi muscles from prime, good and commercial grade beef, to study the effect of various cold storage treatments on losses and on shear tenderness. They showed: (a) the high correlation between heating time and losses; (b) prime grade steaks were more tender than those from the good and commercial grades; (c) the increase in cold storage tended to minimize the grade difference; (d) removal of muscle from the carcass before or during storage, or cutting of the muscle on the carcass, resulted in less tender steaks that those aged on the carcass; and (e) additional cold storage after 3 days aging on the carcass increased the tenderness.

P H AND TENDERNESS

It has also been reported that beef is least tender when the ultimate pH is about 6.0 and increases in tenderness as the ultimate pH increases above or decreases below this value (7,2). In contrast, the tenderness of rabbit (11), sheep (7) and fish (4) has been shown to be greater with higher ultimate pH. The rate of pH decrease can vary among different muscles from individuals of the same or different species (6). In the living animal the pH of resting muscle is about 7.3. It is known that the post-mortem decrease in pH is related to production of lactic acid from glycogen. Thus it is clear that the extent of the pH decrease may depend on the amount of glycogen present in the muscle at the time of slaughter. The glycogen content can be reduced by starvation, exhausting exercise, imposition of pre-slaughter stresses of various sorts, or by struggling at time of slaughter (6).

CONCLUSION

Even though rapid chilling rates reduce the eating quality of the meat, they may be advantageous to the meat industry by improving yield, hygiene, and weight loss. Processing methods should be aimed at minimizing post-mortem shortening which affects tenderness and attention should be given to conditions applied during the period between slaughter and the full development of rigor mortis.

REFERENCES