

COOKING TENDERIZATION OF MEAT

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I. INTRODUCTION

The goal of the animal producer is to provide animals that have the potential for being converted into highly palatable meat products.

Meat tenderness is one of the major palatability factor. There are many factors that influence the tenderness of meat, they can be broadly divided into ante-mortem and post-mortem factors ( 22 ). The ante-mortem factors, include genetic characteristics, physiological factors, feeding and management practices. The post-mortem factors, include length of time and temperature of storage after tenderizing agent, and cooking method.

How palatable a piece of meat is depends upon its characteristics in the form in which it is served, i.e., the cooked state.

Many attempts have been made to relate tenderness to particular muscle components, such as connective tissue and myofibril or to muscle states, such as degrees of muscle hydration and contraction ( 5 ). There are a number of comprehensive reviews on the subject, and one is the relation of tenderness to the cooking of the meat.

II. TENDERNESS OF MUSCLE MEAT

When we cook a piece of meat, a wide range in tenderness occurs among muscles in any one animal. Price and Schweigert ( 22 ) showed the tenderness variations among beef muscle as can be seen in Figure 1.

In general, muscles with least connective tissue, such as psoas major, are the most tender, while the one with the largest connective tissue, such as supraspinatus are the toughest.

Heating psoas major and longissimus muscles to an internal temperature of 70°C, Cheng and Parrish (3) observed a looser packing of myofibrils, thinner myofibril threads and wider I-band regions of the psoas major compare to that longissimus muscle. These might offer an explanation, why steak from psoas major muscle is more tender than steak from longissimus muscle.

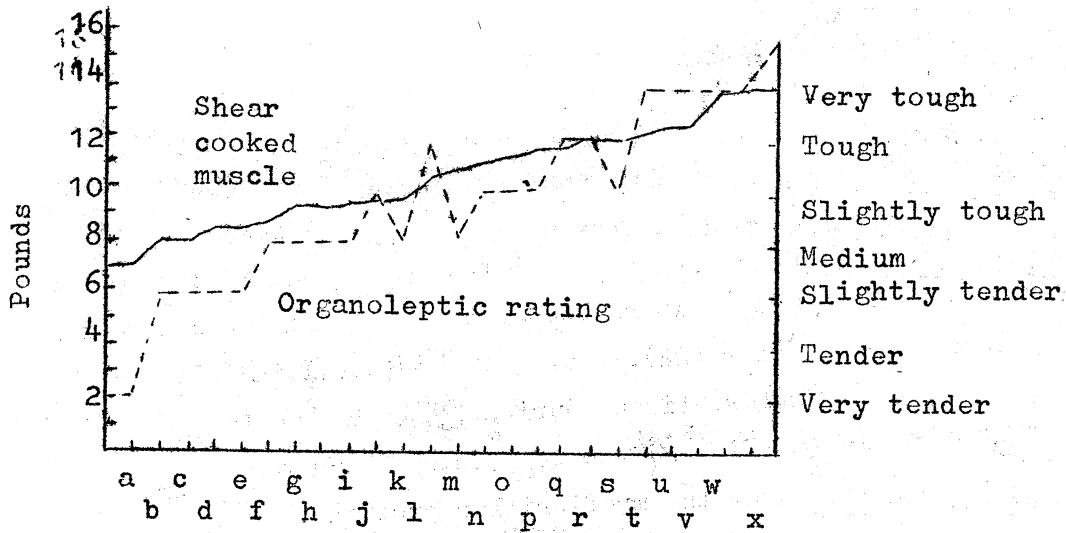


Figure 1. Tenderness variation among beef muscles.

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|----------------------|---------------------|
| a. Psoas major       | m. Semitendinosus   |
| b. Multifidus dorsi  | n. Vastus lateralis |
| c. Infraspinalis     | o. Rectus abdominis |
| d. Gluteus medius    | p. Ext. carpi rad.  |
| e. Longissimus dorsi | q. External oblique |
| f. Triceps brachii   | r. Semimembranosus  |
| g. Biceps femoris    | s. Deep pectoral    |
| g. Supraspinatus     | t. Latissimus dorsi |
| h. Serr. ventralis   | u. Internal oblique |
| i. Rectus femoris    | v. Cutaneous        |
| j. Gastrocnemius     | w. Trapezius        |
| k. Adductor          | x. Super pectoral   |
| l. Ten. fascia lat.  |                     |

Marsh (20) summarize the basis of tenderness of muscle meat. Two muscle components, collagen and the contractile apparatus, determine tenderness. The collagen contribution to toughness is due to the presence of intermolecular crosslinks, which is more thermally resistant and thus less readily broken down during cooking. The contractile protein can cause the muscle to shorten, which is accompanied by a very appreciable toughening. The muscle differences and the effect of cooking on the muscle components, help to explain the differences on tenderness of different meat sample as indicated by shear force measurement.

### III. COOKING TIME AND TEMPERATURE

During cooking, two general changes related to the meat tenderness occur in meat : the muscle fibers become tougher, and the connective tissues become more tender (22). Bouton and Harris (1) indicated that the softening of connective tissue during cooking is due to the conversion of collagen to gelatin and the toughening of meat fibers are due to the heat coagulation of the myofibrillar proteins.

Toughening effect on the fibers and softening on the connective tissue during cooking are both time and temperature dependant. The time factor appears to be more important for muscle fiber toughening (22). However Bouton and Harris (1) stated that tenderness is independent on cooking time for temperature up to 80°C for beef and 60°C for pork, but strongly dependant upon both temperature and cooking time for higher temperatures.

When bovine muscle heated at a 1°C/minute to 60°C and held for 10 hour total heating time, Laakkonen et al (14) found that there were only minor changes in the tenderness for the first 4 hr of heating for longissimus muscle. The major decrease in shear values occurred between the 4<sup>th</sup> and 6<sup>th</sup> hour, when the meat was heated from 50 to 60°C. Many agree that the degree of solubility of collagen increases with temperature, and at about 60°C collagen shortens and converted into gelatin (14). They also indicated that final temperature of meat is extremely critical in affecting the tenderness. If the temperature is below the temperature at which collagen shrinks, the major decrease in tenderness does not occur; if the temperature is higher, severe coagulation of myofibrillar proteins occur, that will cause more tightly packed structure, and less tender meat is obtained.

When they follow the effect of cooking temperatures from 20 to 100°C on tenderness, Davey and Gilbert (5) were able to show two distinct toughening phases ( Figure 2 ).

One between 40 and 50°C, the other between 65 and 75°C. They stated that tenderizing from 80 to 100°C is due to dissolution of connective tissue and probable development of myofibrillar fragility

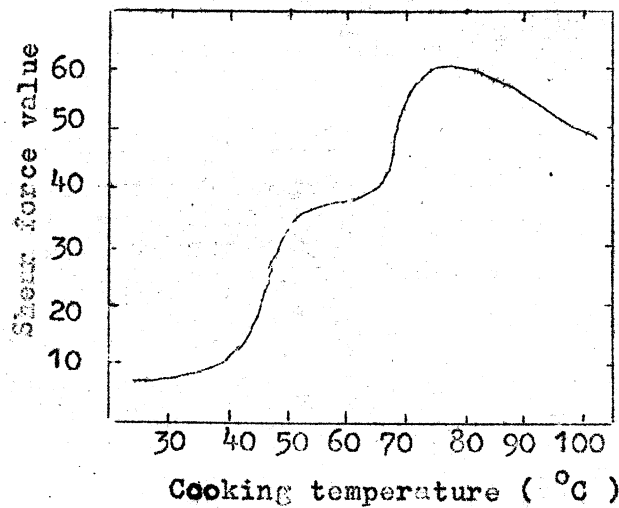


Figure 2. The two-phase effect of cooking temperature on shear-force values.

They also observed that the onset of shrinkage along the fibres of unshortened muscle occurred in parallel with toughening ( Figure 3 ).

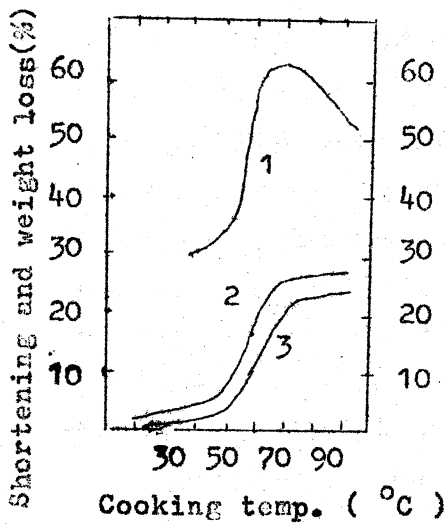


Figure 3. The relationship of the second toughening phase to shrinkage and weight loss. Curve 1, shear-force values ( mean of 6 determinations ), curve 2, shrinkage along the fibres; curve 3, weight loss.

Using the myosin extractability from myofibril as a guide of changes in the actomyosin system, and collagen shrinkage in the connective tissue component, Davey and Gilbert (5) found that myosin extractability of the muscle remained at the maximum with cooking temperatures up to 30°C. There after, it is diminished to virtually zero at a cooking temperature of 60°C (Figure 4). Half change in extractability occurred at 47 to 48°C observed was close to the half change in toughness

in the first phase. The second toughening phase appears to be closely linked to collagen shrinkage.

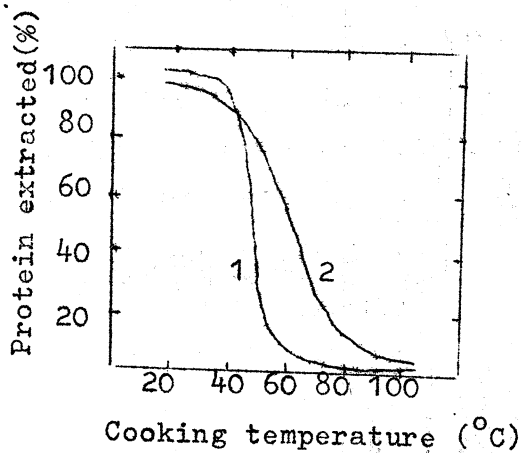


Figure 4. Myosin and sarcoplasmic protein denaturation and collagen shrinkage. Curve 1, percentage denaturation of myosin in myofibril. Curve 2, percentage denaturation of the sarcoplasmic protein in the muscle. Oblong horizontal area, the temperature zone of collagen shrinkage.

Jones (20) summarized the complex changes that occur during heating of muscle: physical-chemical alterations in myofibrillar proteins can be detected at 40°C, coagulation of protein is completed at about 65°C, collagen shrinks at about 58°C, and begins to be converted into gelatin at about 63°C.

Cia and Marsh (4) observed a greater tenderness of the microwave-cooked meat. They believed that this is due primarily to the faster heating in this system. Conventional cooking requires a longer period of heat generation outside, before penetrating inside the meat, whereas with microwave heating there is a rapid generation of heat throughout the tissue. With pre-rigor meat that has a higher pH, slow cooking will result in a significant pH decline, presumably by allowing appreciable glycolysis to proceed in the few minutes before final denaturation. With a microwave oven, the pH will stay high that gives the beneficial effect on tenderness (13).

Using a scanning electron microscope, Cheng and Parrish (3) were able to observe the progressive changes in endomyosial sheath swelling, coagulation and shrinkage. Especially after heating to 70°C, banding patterns and myofibril fragmentation at Z-disks were clearly observed. They also observed that the degradation of collagen fibers in the perimysium was initiated at 70°C and intense disintegration was observed at 80°C.

#### IV. ANTE MORTEM CONDITION

Bouton and Harris (1) indicated that the effect of temperature on the rate and degree of collagenous connective tissue solubilization was dependent on animal age. They found that initially cooking produced a significant change in young steer and significant increases in muscles from old cows. Adhesion value is possibly measure the heat-induced changes in the connective tissue.

Davey and Gilbert (7) found that shear values of old bull (4-7 years old) at zero shortening were only marginally higher than those for young ox (15-20 months old), but it is markedly increase with shortening to S, 0.2.

The effect of heat stress (38°C), Cold stress (4°C) and extreme cold stress (-20°C) before slaughter on the tenderness of chicken breast have been studied. Lee et al (15) found that heat stress significantly increased the toughness of breast muscle of chicken. Cold stress also adversely affected the tenderness. They stated that the shear value was highly correlated to the zero hour glycogen, zero hour pH and ultimate pH of the muscle. Low pH at death (fast glycolysis before death) would produce more tender meat, because large portion of the reserve energy in the muscle was consumed before death while the muscle is still attached to the bone, and therefore, less energy source would be left for the free contraction after excision, resulting smaller degree of shortening and consequently more tender meat (15).

#### V. POST-MORTEM CONDITION

The relationship between the state of contraction of a muscle in rigor and its tenderness as cooked meat has been the subject of intensive study (16). They found that muscles which have not been shortened during rigor, if prevented from shortening during cooking, yield tougher meat. However, when the muscle has been allowed to cold shorten, the tenderness of the cooked meat is not affected by the presence or absence of restraint during cooking. It has been suggested that the differences produced by restraint during cooking could be lie in changes in the number of fibres to be cleaved in the tenderometer of standard size sample.

Using boiling and microwave oven methods of cooking, Cia and Marsh (4) found that meat cooked early postmortem was found to be remarkably tender relative to that cooked after rigor onset. Microscopic examination suggest that the tenderness of meat cooked in a pre-rigor state is largely as a consequence of a shattering of fiber structure in some areas brought about by extreme shortening.

It has been reported that pressure treatment of muscle in a pre-rigor condition, results in shortening and tenderization of muscle (18). One suggestion for the cause of tenderization of the pressure treatment was that myofibrillar structure was broken down by the thick filaments of the severely contracted muscle. As additional factor, a weakening of the filaments might occur by an F-G transformation of actin (19).

When post rigor sternomandibularis beef muscle was frozen then stored at  $-3^{\circ}\text{C}$  for 4 hours to 28 days, a significant decrease in shear force after cooking accrued (23). They believed that freezing disrupts cell membraness, allowing better access of enzymes to substrates and activators, there fore, accelerate the enzyme-catalyzed reaction in the cellular system that induce tenderness.

## VI. SUMMARY

1. There are two factors affect the tenderness of meat during cooking :

### a. Collagen

The presence of intermolecular crosslink that increase with increasing animal age, render the collagen more resistant to heat. This will contribute to the toughness of the meat. However, during cooking several changes might occur. At about  $58^{\circ}\text{C}$ , collagen will shrink, begin converted into gelatin at  $63^{\circ}\text{C}$  and the connective tissue disrupts at about  $80^{\circ}\text{C}$ .

### b. Myofibrillar proteins

A major factor in actomyosin toughness is the degree of shortening in the sarcomere. Heating meat beyond  $30^{\circ}\text{C}$ , will decrease the myosin extractability due to the coagulation of myofibrillar proteins. This will give more tightly packed structure and tough meat.

The coagulation of myofibrillar proteins is completed at about 65°C. Increasing temperature will result looser packing structure, thinner myofibril threads and wider I-band region. This condition was referred as the development of myofibrillar fragility.

2. Toughening effect on the muscle fiber and softening on the connective tissue during cooking are both time and temperature dependant. Therefore, in order to obtain tender cooked meat, the meat has to be heated above the condition in which the development of myofibrillar fragility may occur.

3. Shortening of muscle fiber affect toughness of the meat. However, severe shortening may cause shattering of myofibrillar structure that would give tenderization effect.

4. Any condition that might affect the degree of intermolecular cross-link of the collagen and shortening muscle fiber, therefore, would affect the tenderness of meat

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