UNIT 7 TENDERIZATION OF MEAT

Structure

7.0 OBJECTIVES

After reading this unit, you will be able to:

- explain different methods of meat tenderization;
- apply different tenderizing method suitable for different types of carcass and meats, and
- produce meat with quality that satisfies the ever demanding consumer's needs.

7.1 INTRODUCTION

No palatability factor of meat has received more research study than tenderness. In the developed countries where meat forms a substantial part of daily diet, consumers are very much aware about the tenderness of meat. As all the animals slaughtered for meat do not belong to the same species, age, breed, sex etc., there is huge variation in tenderness of meat obtained from different animals. Sensation of tenderness has several components of varying importance and perception of tenderness by human is very difficult to duplicate by scientific instrumentation. Tenderness of meat is influenced by the breed, age, condition of nutrition and amount of muscular exercise of the animal. It mainly depends on the amount of connective tissue present between muscle fibres and to a lesser extent, on the thickness of muscle fibres themselves. There are several methods by which tough meat obtained from different animals especially aged domestic animals can be converted into reasonably tender meat. In this lesson we will learn about these methods.

7.2 CONDITIONING OF MEAT

Conditioning is the natural process of tenderization when meat is stored or aged post-rigor.

When meat is stored above freezing point at temperatures between 0°C to 3°C, all the changes that usually occur at higher temperatures take place but at a reduced rate. In the absence of microbial spoilage at low temperature, the proteolytic enzymes of muscle fibres bring about a desirable change i.e., conditioning or ripening, which is manifested by a marked increase in flavour, juiciness and tenderness of the meat. The action of enzymes is almost completely inhibited when the meat is stored at temperature below freezing. Bacterial action does not bring conditioning.

During conditioning improvement in tenderness is due to changes in (i) the myofibrils and (ii) the surrounding connective tissue (consisting of collagen and ground substance, proteoglycan). These changes are brought about by multicatalytic proteinase complex, calcium activated proteases, the calpains and the lysosomal cysteine proteases, the cathepsins. Calpains and multicatalytic proteinase complex both are present in sarcoplasm. The calpains are calcium dependent enzymes and they have a specific inhibitor calpastatin which is also present in the sarcoplasm of muscle fibres. The calpains differ in their calcium requirement for activation. There are two forms of calpains namely, m-calpain and μ-calpain. m-calpain is activated by high concentration of calcium ion and μ-calpain is activated by low concentration. Calpains are also called as CASF (calcium activated sarcoplasmic factor). There are several proteolytic enzymes in lysosome. The cathepsins in lysosome are found in different forms B, D and L. You have already learnt about the micro structure of muscle fibre and myofibrils and also know that sarcomere lies between two Z-lines. Sarcomeres are the functional units within myofibrils. These enzymes, calpains and cathepsins cause a degradation of the Z-discs which separate the sarcomeres. Due to degradation of Z-discs and separation of sarcomeres, there is loosening of myofibrillar structure which results in the reduction in toughness, although actomyosin formed during rigor mortis remains intact. Besides the changes in myofibrillar structures during conditioning, there is some degree of degradation in the surrounding connective tissue structure also which further aids the meat to be more tender. The structural site where the proteolytic enzymes act can be summarized as below:

(i) **Calpains/CASF:** They act on troponin T (above p^H 6), Z-lines (desmin), connectin, gap filaments, M line proteins and tropomyosin.

(ii) **Lysososomal enzymes:** They act on troponin T and I (below p^H 6), C protein, myosin, actin, tropomysin, a-actinin, nebulin, titin (above p^H 5), cross links of non-helical telopeptides of collagen and mucopolysaccharides of ground substance.

Procedure recommended for the commercial conditioning of beef:

(i) The dressed carcass should be chilled at -0.5 to 3°C for 1 – 2 days and then made into quarters.

(ii) The sides or quarters should be held at 2 to 3°C for 10 – 12 days.

(iii) Before cutting up or removal for retail sale, the quarters should be held at ordinary room temperature. If the room temperature is too high they should be held at 4.5 to 7°C for 24 hours.

In commercial practice, conditioning of meat is limited to 2 – 6 weeks and when beef is cut into small joints the greatest increase in palatability is ensured by a storage period of about 9 days.

7.3 TENDERSTRETCH METHOD

It has been known for long time that while stretching of muscles produces a tenderizing effect; shortening produces the opposite effect that is toughening of meat. Traditionally, beef sides or whole carcasses are hanged by means of a hook, inserted behind the Achilles tendon during conditioning. The weight of the carcass put many muscles into tension so stretching them as they pass into rigor. This stretching helps to increase sarcomere length and thereby to produce more tender meat. But a new method of hanging beef sides from aitch bone (with the help of a hook inserted into the obturator foramen or "pope's eye") has been shown to prevent the muscle of hind limbs from shortening and subsequent toughening. In this posture muscles of hind limbs assume a relaxed position. The process is called pelvic suspension or hip free suspension. The hot beef sides or quarters must be suspended by the aitch bone within one and half hour of slaughter. After pelvic hanging, the shape of the carcass becomes unconventional and the carcass takes more space in the chiller. To bring the carcass to near-normal shape, it can be hanged from Achilles tendon in a chiller after 24 hours of hanging by aitch bone. The improvement in the tenderness of rump, thick flank, strip loin and scotch fillet is said to be equivalent to 3 weeks of ageing at 2°C. Similar improvement in sheep and goat carcasses can be achieved by the tender-stretch method.

Pelvic Hanging

Fig. 7.1: Pelvic suspension

7.4 TENDER CUT PROCESS

In this process, tension on individual muscles in a suspended carcass is reduced by selectively severing the bones and ligaments. The carcasses are suspended normally from the Achilles tendon and thus it is easy to implement on commercial slaughter lines. When the process is carried out within 45 minutes of slaughter, a significant improvement in tenderness has been noticed both in cattle and pig carcass meats.

7.5 ELECTRICAL STIMULATION (ES)

Electrical stimulation of carcass following slaughter is the new commercial method of meat tenderization. ES was first introduced in New Zealand in an attempt to avoid the cold shortening of muscle resulting from too rapid cooling of lamb carcasses. Now, it is widely practiced in meat industry world over. ES is the application of sufficient current into the carcass during the slaughter process. Here, pulses of electricity are passed through the carcass immediately after slaughter and the current causing the muscles to contract and thereby use up glycogen, ATP and creatine phosphate. It is done before rigor or in-pre-rigor carcass.

The electrical stimulation of pre-rigor muscle causes the carcass to undergo a rapid series of muscle contractions and relaxations. The rapid series of contractions and relaxations of muscle accelerates the rigor process.

Time of electrical stimulation: Electrical stimulation can be performed at any stage. It is better to be given within 30 minutes of bleeding; otherwise the muscles will lose their capacity to react to the electrical stimulation. As the length of time between bleeding and stimulation is increased, electrical stimulation becomes less effective since postmortem resistance develops and muscles of these carcasses can be shortened and tough.

Category of animals suitable for E.S: ES is more applied to carcasses from sheep/goat and cattle than pig. Cold shortening is less of a potential problem with pork carcasses because in pork carcass, the development of rigor mortis is quicker. However, with very fast chilling procedures, stimulation may be beneficial.

Advantages of electrical stimulation on carcass:

- Improves the quality of meat from aged or spent animals.
- Increases tenderness and reduces ageing times.
- Improves appearance and colour of lean.
- Can advance the process of rigor mortis.
- Avoids cold shortening and thaw rigor.

Methods of electrical stimulation:

There are two recognized methods of electrical stimulation:

(a) High voltage stimulation (greater than 500 volts even upto 1000 volts).

(b) Low voltage stimulation (less than 75 volts).

The current can be applied through various combinations of electrodes but usually it is done between muzzle or nose, the chest and hind legs of animals. Usually the current is applied as a series of pulses of 1-2 second duration and for a period of upto 90 seconds.

(a) **High voltage stimulation:** High voltage stimulation systems are more expensive than low voltage stimulation and have complex safety mechanism to prevent accidental electrocution of workers. In this system, the muscle gets direct stimulation due to flow of current and generally does not depend on

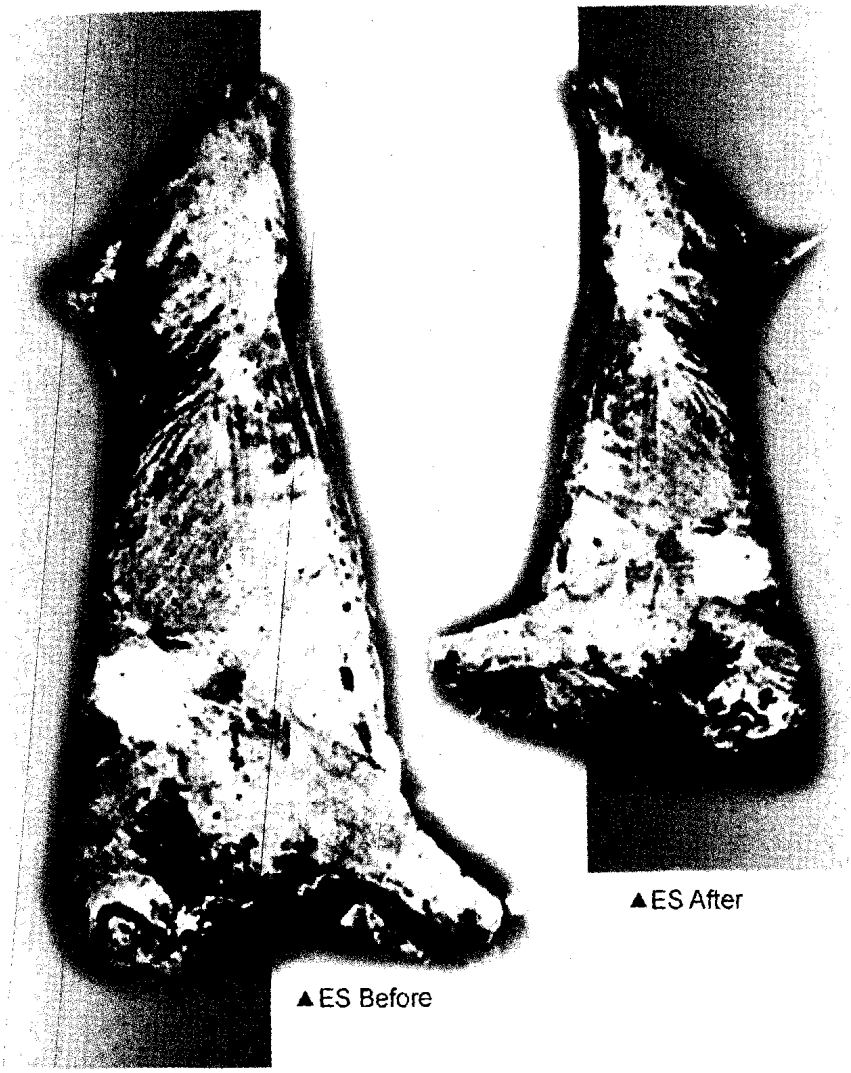

Fig. 7.2: Effect of electrical stimulation (ES)

animal's nervous system. High voltage is effective in accelerating postmortem glycolysis for 1.5 to 2 minutes. This system can be applied much later of bleeding.

(b) **Low voltage stimulation:** It is a cheaper system where complex safety equipment is not needed. But it is considerably slower process. Low voltage systems are usually applied immediately after bleeding. Here, muscle gets stimulation through nervous system.

Table 7.1: Low voltage and high voltage electrical stimulation

Parameters	Low voltage ES	High voltage ES
Voltage used	20 - 100Volts	500 - 1000Volts
Current	< 1ampere	> 5 amperes
Duration of Current application	for upto 20 seconds	for up to 90 seconds
Time of application	applied immediately after exsanguinations (within 5 minutes of stunning)	applied up to 60 minutes post-mortem (but more usually earlier than this)
Mode of action	stimulates muscles through nervous system	stimulates muscles directly

Source: P.D. Warriss (2000): Meat Science — An Introductory Text (CABI Publ.)

7.6 TENDERIZATION BY INFUSION OF CALCIUM CHLORIDE

Experiments conducted on use of calcium chloride in pre-rigor meat indicate that by increasing the calcium level/concentration in muscles, the process of ageing (conditioning) could be accelerated. Measurements suggest that after one day of ageing, calcium chloride - infused bovine muscle was similar in tenderness to control cuts that had been aged for 7 to 14 days. For goat meat, a holding period of 3 days after injecting calcium chloride solution within 2-3 hours of slaughter was found necessary for improving tenderness of meat. Increased concentration of calcium ion weakens the structures of myofibrillar desmin intermediate filaments, and probably the endomysium and perimysium, thereby makes the meat more tender.

Advantages of calcium chloride infusion:

- No over-tenderization of meat.
- No requirement of special equipment.
- Easy adaptability of the process at retail level including household and restaurant levels.
- Fortification of calcium level in the meat.

7.7 MECHANICAL TENDERIZATION

Mechanical methods such as needle or blade tenderization, steak maceration, tumbling, massaging, grinding, cubing etc. are effective methods for improving tenderness.

Needle or blade tenderization is accomplished by passing the steaks (or boneless sub-primals) through blades and/or a bank of needles. The blades and/or bank of needles pass through the meat, severing connective tissues and muscle fibres, making the meat more palatable. A variable speed conveyor is used to advance the meat, while the up-and-down motion of the needle bank penetrates the muscle tissue. The best results are obtained when boneless sub-primals such as boneless rib-eye and boneless top sirloin are used.

Generally tumbling and massaging are used synergistically with marination for better and faster penetration and uniform distribution of cure and simultaneous improvement in tenderness. The steak macerator can be used for tenderizing individual loin, sirloin and round steaks. However, it is used more often to make cubed steaks from less tender portions of the carcass such as chuck (shoulder).

Grinding is a very popular means of increasing tenderness of meat, especially beef. Ground meat is more popular than steaks and roasts due to its uniform texture and tenderness. Another means of mechanical tenderization is cubing where the small blades of a cuber simply severe connective tissue in boneless retail cuts to break the tissue into smaller pieces.

7.8 TENDERIZATION BY ENZYMES

Several attempts have been made to make the tough meat tender by use of several proteolytic enzymes obtained from plants, bacteria and fungi. Enzymes which have been used for tenderizing meat include papain, a proteolytic enzyme from papaya fruit (*Carica papaya*); ficin, a protease derived from figs ; bromelin, a proteolytic enzyme of pine apple besides bacterial and fungal enzymes such as protease 15, rhozyme, fungal amylase, hydralase D etc. These tenderizers can be used in liquid or powder form and in both cases, at commercial level or in the home.

Bacterial and fungal proteolytic enzymes act only on the proteins of muscle fibre causing digestion of sarcolemma, disappearance of nuclei, degradation of muscle fibre and eventually loss of cross-striations. Proteolytic enzymes of plant origin act preferentially against connective tissue proteins. Main features of these enzymes are that they do not attack native collagen as it is denatured by heat during cooking. They break down the heat denatured connective tissue proteins to soluble, hydroxyproline containing molecules.

Methods of application of proteolytic enzymes:

(i) Dipping of meat in enzyme solution.

(ii) Introduction of enzyme solution into the meat pieces through fork holes before cooking.

(iii) Pumping the major blood vessels of meat cuts post-mortem with enzyme containing solution.

(iv) Rehydrating freeze dried steaks in a solution containing proteolytic enzymes.

(v) Pre-slaughter injection (10 - 15 minutes before slaughter) of solution (0.5 mg/lb live weight; 5- 10 per cent solution) containing enzymes.

*The last method is considered to be the best. After the injection, the animal should be slaughtered within 10 to 15 minutes, the optimum time range for maximum tenderness. The enzyme is activated during cooking at an optimum temperature of 60 to 70°C and causes tenderization of meat.

7.9 HIGH PRESSURE TENDERIZATION

The application of pressure upto 150 Megapascal to muscle and related systems has revealed responses of considerable magnitude and potential usefulness. The post-mortem glycolysis can be controlled to a great extent and it can be so accelerated that it is virtually completed within few minutes. Meat of any desired p^H value in the usual post-mortem range can be produced. The pressure treatment also causes changes in other structure of muscle and results in tenderization. Z-line degradation is found in pressure treated muscle fibre. This is due to the Ca^+ dependant protease that is released when the mitochondria and the sarcoplasmic reticulum are affected by high pressure.

A procedure has also been developed for pressure tenderization of post-rigor muscle. It provides the only means by which toughness due to muscle contraction can be eliminated in intact post-rigor muscle but it is necessary to heat the meat to about 60°C for 30 minutes during treatment. This combined pressure — heat treatment result in a substantial decrease in shear force value even in cold shortened muscle. The treated meat has a cooked appearance. Pressure also influences the action of salt in the swelling of muscle tissues and the dissolution of muscle proteins.

7.10 MISCELLANEOUS TENDERIZING AGENTS

Tenderization by Ginger Extract: Ginger is widely used in household and restaurants for preparation of various culinary dishes because of its spicy flavour imparting properties. Recently, ginger rhizome was investigated as a new source of proteolytic enzyme of plant origin. Proteolytic enzyme isolated from ginger rhizome is known as *Zingibain*. Proteolytic activity of this enzyme was found to be many times greater on collagen than on actomyosin thereby considered to be effective for tenderizing meat from old animals. Ginger extract also possesses antioxidant and antimicrobial properties making it more beneficial for fast food facilities serving pre-cooked meat. This ginger extract has been shown to be very effective in improving tenderness and other sensory characteristics of spent hen meat and mutton.

Tenderization of Cucumis Trigonus: Cucumis plant is a wild plant found in India. The dried fruits of this plant are used traditionally during cooking of meat to improve taste. It has been observed that protease named *cucumin* obtained from fruit of *Cucumis trigonus* has good proteolytic activity. The crude extract of dried cucumis fruit was found to improve tenderness and overall palatability of pork and buffalo meat. It had been reported that dried cucumis powder has higher proteolytic activity than fresh peels and action is more evident on myofibrillar protein than on connective tissue protein. Due to its easy availability and being cheap, this has potential to become a better alternative to other proteases, chemicals etc. used for tenderization.

Use of Salt and Phosphate as Tenderizer: Sodium chloride itself and other salts have a tenderizing action on meat. Post-mortem perfusion of joints with salt solution has been reported to improve the tenderness of meat. This action is mainly due to enhanced water holding capacity as seen in case of application of alkaline polyphosphates. Use of alkaline polyphosphates has been found to be very effective in improving tenderness, juiciness and overall palatability of spent hen, sheep meat and buffalo meat. Polyphosphate (Tetra sodium pyrophosphate, trisodium polyphosphate etc.) solution either can be injected into meat pieces or the meat pieces can be cured in polyphosphate solution for 12 to 48 hours for improvement in tenderness, juiciness and overall palatability of meat.

7.11 TENDERIZATION BY MARINATION

We can improve the tenderness of meat and add taste variety to the meat components of meals by a process of marination. The basic ingredients of a marinate include salt, acid (vinegar, lemon or soy sauce) and enzymes (papain, bromelin and ginger extract). Addition of a little amount of oil seals the surfaces of meat from air and results in fresher and brighter appearance of meat for a longer period of time. Marination tenderizes the meat through the softening of collagen by the salt and hydrolysis and breakage of the cross-links of the connective tissue by the acids and alcohols. Meat is cut into small pieces or strips to help complete penetration of the marinate into the center of the meat. Then the meat is mixed with the marinating ingredients and kept in refrigerator for a minimum of 4-8 hours for complete marination.

7.12 COOKING

Cooking plays two different role in tenderness of meat. The contractile proteins i.e., myofibrillar proteins of meat become less tender due to coagulation during cooking process. On the other hand, major connective tissue protein i.e., collagen is converted into gelatin by cooking and becomes more tender. Cuts such as steaks and chops from the ribs and loin are low in connective tissue. Dry heat cooking like, pan frying, broiling, roasting or barbecuing is recommended for such cuts because dry heat raises the temperature very quickly to develop flavour of meat before the contractile proteins have the opportunity to become significantly less tender. Moist heat cooking such as braising is recommended for cuts like fore shank, round and chuck which are having a high amount of connective tissue because application of moist heat for a long time at low temperature converts collagen into gelatin and makes the meat tender. Tenderness is also affected by degree of doneness. When the lean is heated, the contractile proteins toughen, moisture is lost and tenderness decreases. Meat cooked to rare degree of doneness (140^{0}F) are more tender than that cooked to medium degree of doneness (155^{0}F) and the later one is more tender than well-done (170^{0}F). Degree of doneness is important for beef because some people like flavour of well-done beef than rare beef. Beef with little marbling requires less cooking

time than higher grade beef. Pork is cooked to 160^{0}F-170^{0}F internal temperature for desirable flavour and production of trichina free meat as trichina dies at 137^{0}F. It is usually recommended to cook lamb to well-done (160^{0}F-170^{0}F internal temperature) for desirable flavour.

Check Your Progress

1) Enumerate different methods of meat tenderization.

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2) What is conditioning/ageing of meat? How will you condition/age beef?

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3) What are the different proteolytic enzymes used for tenderization of meat?

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4) Write a short note on tenderstretch method.

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5) What are the advantages of electrical stimulation?

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6) How does high pressure help in tenderization process?

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7) How does ginger extract act as a tenderizing agent?

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8) What method of cooking will you recommend for meat cuts with low connective tissue and why?

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9) How does marination tenderize the meat?

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7.13 LET US SUM UP

Tenderness of meat is the most widely studied eating quality parameter. Most of the consumers all over the world prefer tender meat in their diet. Therefore, a number of methods have been developed to convert the tough meat obtained from aged animals into tender one. Out of these methods most important is the conditioning or ageing which is mostly applied to beef and mutton. It is the process of holding meat just above its freezing point for a considerable time to improve its tenderness, flavour and juiciness. This does not happen due to microbial action; on the contrary due to action of endogenous proteases (calpains and cathepsins) which bring out the subtle changes in the quality of meat. To improve further, tenderstretch method has been advocated during conditioning. Meat industry has adopted electrical stimulation as a method to prevent 'cold shortening' in the carcasses and thereby improve tenderness indirectly. Mechanical tenderization (blade tenderization, steak maceration, massaging, tumbling etc.) is very useful for boneless sub-primals to improve their quality including tenderness. Other important methods of tenderization include application of proteolytic enzymes of both plant and microbial origin. Indigenous tenderizing agents such as ginger extract, powder of dried cucumis fruits have been tried with varied rate of success. Beside these, salt and alkaline polyphosphates are also applied to meat to improve eating quality parameter including tenderness. Marination of the meat with acid, alcohol, salt etc. and cooking of different temperature also play important role in tenderness of meat.

7.14 KEY WORDS

Calpains : Calcium activated proteases (enzymes) present in the muscle itself.

Cold shortening : When pre-rigor meat is subjected to very fast chilling, severe shortening accompanied by toughening of muscle occurs.

Electrical stimulation : Application of sufficient current into the carcass during slaughter process to accelerate the rigor processand tenderize the meat.

Marination : The process which tenderizes meat and adds taste to meat by use of salt, acids, enzymes and alcohol.

Pope's eye : Obturator foramen in the pelvic girdle is called pope's eye. With the help of a hook carcasses are hanged from aitch bone by inserting it into the obturator foramen.

Tenderstretch method : Hanging of the carcass from pelvic girdle results in stretching of the muscles which makes the meat tender after cooking. This process is called tenderstretch method.

7.15 SOME USEFUL BOOKS

Biswas, S. (2005). *Meat and Egg Technology*, 1st ed., University Publication, WBUAFS, West Bengal..

Forrest, J.C., Aberle, E.D., Hedrick, H.B., Judge, M.D. and Merkel, R.A. (1975). *Principles of Meat Science*, W.H. Freeman and Company, San Fransisco.

Lawrie, R.A. (1998). *Lawrie's Meat Science*, 6th ed., Woodhead Publishing Limited, London.

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7.16 ANSWERS TO CHECK YOUR PROGRESS

1) Different methods of tenderization are listed below:
   - (i) Conditioning/ageing meat
   - (ii) Tenderstretch method
   - (iii) Tender cut method
   - (iv) Electrical stimulation
   - (v) Infusion of calcium chloride
   - (vi) Mechanical Tenderization
     - (a) Needle or blade tenderization
     - (b) Steak maceration
     - (c) Tumbling and massaging.
     - (d) Grinding
     - (e) Cubing
   - (vii) Tenderization by enzymes
   - (viii) High pressure tenderization
   - (ix) By miscellaneous tenderizing agents
     - (a) Tenderization by ginger extract
     - (b) Tenderization by *Cucumis trigonus*
     - (c) Use of salt and polyphosphate as tenderizer
   - (x) Marination
   - (xi) Cooking.

2) In the absence of microbial spoilage, holding of fresh meat above its freezing point for a specified period of time to improve the tenderness, juiciness and flavour of meat is known as conditioning/ageing.

A procedure recommended for commercial conditioning of beef is

   - (i) The dressed carcass should be chilled at –0.5 to 3°C for 1 to 2 days and then should be made it into quarters.
   - (ii) The sides or quarters should be held at 2 to 3°C for 10 to 12 days.

(iii) Before cutting up or removal for retail sale, the quarters should be held at ordinary room temperature. If the room temperature is too high they should be held at 4.5 to 7°C for 24 hours.

3) Following proteolytic enzymes are used for tenderization of meat:

Plant origin enzymes include:

- Papain from papaya,
- Ficin from fig
- Bromelin from pine apple.

Bacterial and fungal origin enzymes used are:

- Protease 15
- Rhozyme,
- Fungal amylase
- Hydrolase D.

4) Traditionally, beef sides or whole carcasses are hanged by means of a hook inserted behind Achilles tendon during conditioning. A new method of hanging beef sides from aitch bone with the help of a hook inserted into obturator foramen has been shown to prevent the muscles of hind limbs from shortening and subsequent toughening. In this posture, muscles of hind limb assume a relaxed position. It is better to hang the hot sides or quarters from aitch bone within one and half hour of slaughter to get optimum benefit of the process. After 24 hours they can be hanged from Achilles tendon as usual. The improvement in tenderness is noticeable in the rump, thick flank and strip loin and it is said to be equivalent to 3 weeks of ageing at 2°C.

5) Advantages of electrical stimulation are following:

- Improvement of meat quality from aged or spent animals.
- Increment of tenderness and reduction of ageing time.
- Better appearance and colour of meat.
- Acceleration of rigor process.
- Prevention of cold shortening and thaw rigor.

6) High pressure helps in tenderization by following means:

- Accelerates post-mortem glycolysis to such an extent that it is completed within few minutes.
- Changes structure of meat.
- Produces desired p^H of meat in the usual post-mortem range.
- Influences the action of salt in the swelling of muscle tissues and the dissolution of muscle proteins.

7) Ginger extract contains a proteolytic enzyme – zingibain. This enzyme tenderizes meat by acting on collagen (greatly) and actomyosin complex (slightly).

8) Dry heat cooking like pan frying, broiling, roasting or barbecuing is recommended for the meat cuts with low connective tissue because temperature of the meat is increased very quickly to develop flavour before contractile proteins become tough.

9) Marination tenderizes the meat through —

- Softening of collagen by salt
- Hydrolysis
- Breakage of cross links of the connective tissue by acid and alcohol.

Notes