Methods for Enhancing Meat Tenderness a Main Key Factor of Meat Palatability: A Review

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ABSTRACT

The consumers now ask for nutritions high quality foods and food products. The main quality factors and attributes of meat and meat products acceptability and salability are colour, texture, flavour, juiciness, and tenderness. Tenderness is major determinant parameter of meat quality. Research and development studies were carried out using traditional and novel technology to maximize meat tenderness. Chilling temperatures at the pre- and post-rigor stage, have a significant effect on toughness and tenderness of meat. The applications of green non-thermal, energy saving, and quick technologies are now in use in the meat industry for enhancing meat tenderness and other meat palatability characteristics. Maximizing meat tenderness can be achieved through traditional and novel methods. Enhancing meat tenderness can be achieved by ageing, electrical stimulations, electric pulses, exogenous and endogenous proteases, shockwaves, ultrasonic, tumbling, tender bound vacuum packaging, mechanical or chemical infusion methods. Tenderness is an important consumers' desirable factor concerned with soft chewing and cutting of meat. Tenderness and juiciness are two of the major determinant eating parameters of meat qualify, as assessed by the consumers. The tenderness process plays a marked effect on the macrostrains, connective tissues, muscle fibers cells enzymes and proteins. Enhancing meat tenderness cab be accompanied by improving other quality and palatability parameters, as increasing flavour and juiciness. On the other hand, drip as well as cooking loss are decreased by improving tenderness. Meat tenderness is a main factor in increasing the overall acceptability and the marketing value of all meat cuts, particularly those of low value. The choice of the cooking method should achieve an evenly cooked tender, and juicy meat based on the meat cut and the costumer preference.

Keywords: meat tenderness, shockwaves, methods for enhancement .

INTRODUCTION

The overall acceptability of raw or processed food products is based on different quality characteristic. The parameters of quality factors are markedly different between various food commodities. whether being of animal or plant origin. The main quality factors and attributes of meat and meat products are colour, texture flavour (taste and odour), juiciness and tenderness. All these quality factors play an important role in meat acceptability (Breidenstein & Carpenter,1983). The quality of meat is markedly affected by many factors conserned with the species and age of the animal, as well as the conditions before, during, and after slaughter. Grunert *et. al.* (2004) and Troy & Kerry (2010) reviewed and cover the consumer perception and development of quality factors of meat and meat products. Tenderness is an important consumers desirable factor, which is concerned with soft chewing and cutting of meat. Tenderness and juiciness are of the major determinant eating parameters of meat quality, as assessed by consumers. The present review highlights many main information about the factors that play an important role in meat tenderness. The applications of non-thermal, energy saving, green, and quick technologies are now recommended for use in the meat industry for enhancing meat tenderness and other palatability characteristics.

Controlling and optimizing the environmental conditions of animal growth (cows, pigs, and sheep) showed a great impact on meat tenderness and other meat multifactorial quality factors, according to Meat and Livestock Commission (1991). (1993) and (1995). According to Koohmaraie (1996) the toughness and tenderness of meat is regulated by some biochemical effects. Molony *et. al.* (2001) reported that tender and rich flavour beef can be produced with improved nutritional rations. Maltin *et. al.* (2003) indicated that it is clear that meat tenderness is affected by animal breed and nutrition, type

of muscle fibers, degree of muscle buffering effect and many other postmortem conditions. Mullena *et. al.* (2017) reported that the consumers need for high - quality meat and novel meat products is increasing. Generally, the tenderized meat has many benefits, as the less cooking time, soft texture, accepted juiciness, easy to cut and chew. In general. render meat shows great economic value as well as high degree of acceptance and palatability.

Postmortem

The water holding capacity, juiciness and tenderness of meat are affected by the biochemical conditions of postmortem (Huff-Lonergan & Lonergan 2005). The postmortem bioreactions are mainly enzymatic as reported in details by Kemp *et. al.* (20l0). Biochemical changes which naturally occur in the animal muscles after death or slaughter, is known as rigor mortis. These changes according to Vinayak (2021) are linked with other factors as animal species, breed, stress, slaughter method, and post - slaughter chilling conditions. Direct placing of the meat or carcass after slaughter at low temperature or freezing resulted in prolong rigor mortis and irreversible toughness. Rigor mortis causes stiffening of muscles after slaughter, where the meat is firm and tough for several hours up to many days. That is due to the depletion of adenosine triphosphate. which is necessary for muscle relaxation. Such post slaughter conditions resulted in meat toughness. Shi *et. al.* (2021) investigated various mechanisms for effective postmortem meat tenderization. The postmortem significantly affects all the characteristics of meat quality. Variation in tenderness or toughness is the main parameter mainly affected through the post mortem changes, as it is particularly related to the biochemical changes and proteolysis, which occur in the postmortem carcasses and muscles. Greta *et. al.* (2024) reviewed the changes of proteomics some other biological parameters during postmortem and meat aging.

Recently, Zhang & Lui (2024) investigated the expression of proteins and their role in postmortem. Certain and different modified proteins are considered as biomarkers in relation meat tenderness, based on proteomics studies. They explained that seven protein biomarkers are involved in tenderness pass way reactions. The seven group biomarkers, namely, some protein related to stress action some enzymes related to the metabolic process, process, myofibrillar proteins, components dealing with calcium, heat shock proteins and apoptotic proteins. Further studies and investigations. Based on the scale proteomic components, can relation to maximizing meat tenderness.

Electrical Stimulations (ES)

Electrical stimulations (ES) were carried out on a commercial scale in New Zealand in 1970s, to avoid cold shortening and toughness of lamb carcasses upon rapid freezing, Strydom & Frylinck (2014). ES was found to enhance tenderness of beef and sheep meat due to some biochemical reactions and physical changes. ES resulted in fast glycolysis with lactic acid production and fall of meat pH can be below 6. Accordingly, the cold shortening of muscles was avoided upon chilling before the carcass temperature becomes 10°C according to Hwang *et. al.* (2003) and Strydom & Frylinck (2014).

Troy (2006) reported that hot boning of meat is an immersion process in the meat industry. Pouliot *et. al.* (2014) demonstrated that ageing started earlier in ES heavy lambs than in the non- treated animals. ES can be used for hastening the onset and resolution of rigor mortis. That treatment has many benefits in meat industry as reducing time and labor as well as marked improvement of meat tenderness and other quality parameters for hastening the onset and resolution of rigor mortis. That treatment has many benefits in meat industry as reducing time and labor as well as marked improvement of meat tenderness and other quality parameters as demonstrated by Kazeem & Awis (2014). Contreras-Castillo *et. al.* (2016) investigated the effect of ES on the degradation of myofibrillar protein, as well as its effect on small heat shock protein in postmortem beef.

ES is now widely used in many meat-producing countries as New Zealand, Australia, the USA, South Africa, India, and to some extent in some European countries. In conclusion, though ES has marked beneficial effect on meat tenderness. yet the process is not used on a universal scale. Webb & Agbeniga (2020) concluded that ES at low voltage with controlled timing and duration resulted in light and heavy cattle meat tenderization due to fast postmortem. Muhammad *et. al.* (2021) indicated that ES and suspending showed an effect on meat quality.

Meat Ageing

Glycogen stored in animal muscles is converted to lactic acid, which is accumulated and reduces the carcass pH. The water holding capacity, juiciness and tenderness of meat are improved by proper chilling and ageing conditions. Accordingly, depletion of the muscle stored glycogen before slaughter, should be avoided. Meat ageing (aging) is an enzymatic process where the microbial and muscle enzymes break down the complex proteins. Accordingly, both of tenderness and flavour of the meat have been improved. This can be done by either wet or dry ageing.

Dry ageing is carried out in open air under controlled conditions of temperature. while wet ageing takes place in packaged vacuum sealed meat cuts. Wet ageing markedly improve both of tenderness and the natural flavour of meat Kim *et. al.* (2016). Solji *et. al.* (2022) studied the effect of different aging conditions on meat quality. The study showed same quality and microbial properties. The exudate of wet aged two cuts of beef up to 23 days at 2°C. can be used as a real analytical method to assess changes and quality parameters of aged meat as demonstrated by Derico *et. al.* (2023). Their study was based on the content of major proteomes and metabolites of the beef exudate. The European Food Safety Authority (2023) stated that meat aged under controlled conditions, is safe as fresh meat. Representing no risk hazards. Syahira *et. al.* (2024) noted that aging did not result in reducing the meat toughness of meat cuts derived from old animals. Such tough cuts can be tenderized by other methods, suitable for the degradation of connective tissues and the proteins of the myofibril.

Pulsed Electrical Field (PEF)

Pulsed electrical field (PEF) technology finds its way in some sectors of the food industry. Bekhit *et. al.* (2016) found that repeated application of PEF treatment showed an effect on the quality of two cuts of hot-boned beef. The benefit of using PEF is that it lasts short time at low temperature. The food through PEF treatment, is exposed by placing or passing between two electrodes to the desired electric pulse and duration (Bhat *et. al.*, 2018, 2019, Morton *et. al.*, 2019). Many investigations proofed that PEF improved muscle tenderness during ageing, and the PEF can be adjusted according to individual muscles.

Gomez *et. al.* (2019) and Bhat *et. al.* (2019) indicated that the PEF is a promising field in the current and future of meat and fish processing industry. Ume *et. al.* (2023) indicated that PEF improved chicken meat quality as flavour and tenderness were stimulated as related to some amino acids stability. PEF has importance and application of PEF in food industry (Zhang *et. al.*, 2023).

Enzymatic Tenderization

Dransfield & Etherington (1981) reported that enzymes are proper natural biological agents for use in meat tenderization. According to Konno *et. al.* (2004) papain as a cysteine protease protects plants from the insects attacking the plant. Calkin & Sullivan (2007) markedly improved beef tenderness by enzymes. Grzonka *et. al.* (2007) and Liu *et. al.* (2008) reported that cysteine proteases and other proteases are important active biological sources for their effective functions. Maiti *et. al.* (2008) reviewed the use of natural meat tenderizers. Maróstica & Pastore (2010) and Pietrasik & Shand (2011) covered some factors that showed marked effect on the application of enzymes in meat and meat products industry.

Sensory quality of beef was improved by papain injection and treatment according to Anderson *et. al.* (2012) and Akpan and Omojola, (2015). Ha *et. al.* (2012) and Ha *et. al.* (2013) demonstrated that many commercial preparations of plant origin (papair, bromelain, actinidin and zingibain proteases) and microbial sources (bacterial and fungal proteases) are available for industrial use, particularly for meat tenderization. Papain. bromelain, elastase and proteolytic microbial enzymes, and other exogenous proteases can be used to improve beef tenderness, (Ashie *et. al.*, 2002, Chen *et. al.*, 2006, Ketnawa & Rawdkuen, 2011, Bekhit *et. al.*, 2014a,b, Chaurasiya *et. al.* 2015). Abdel-Naeem & Mohamed (2016) indicated that the addition of papain and ginger extract improved both of the muscle structure and sensory properties of formulated camel meat burger. Ahmed *et. al.* (2020) investigated the use of an extracted protease of cashew fruit for meat tenderization. Morellon *et. al.* (2020) indicated that plant proteases are preferred by the consumers for meat tenderization compared to animal and microbial sources, for safety, religious, and possible allergenic aspects.

El-Zalaki (2021a,b) assessed the quality of meat tenderized by papain and oryzae proteases by

sensory chemical, and histological methods. The results revealed that marked effect was demonstrated by papain treatment on raw (Fig. 1), papain treated (Fig 2), and cooked papain treated meat (Fig. 3). Generally, Verma *et. al.* (2022) reported the importance of extracted plant enzymes in the food industries.

Shockwave Tenderization

Shockwave technology is the use of a hydro-pressure processing, which is considered as mechanical Underwater Shockwave Processing (USP). It is carried out by the use of mechanical pressure pulses of water placed in a large tank. The mechanical effect of the waves disrupts and tears the matter, exposed to it, according to their different properties. Wave can be easily calculated by developed software application and imaging system.

Bolumar *et. al.* (2013) developed shockwave as a promising technology intended for future use in the industry of meat tenderization, the opportunities and expected challenges were covered. Tomas *et. al.* (2013) reviewed the use and challenges facing the use of shockwave in meat tenderness industry. The effect of shockwaves on muscle peptidases, cathepsins, microstructure and tenderness was studied by Bolumar *et. al.* (2014). They stated that the rupture effect of shockwaves, caused in the muscles, resulted in instant softening with no negative effect on either the microbial or the chemical structure of meat.

Bolumar & Toepfl (2016) covered the application of shockwave technology as an innovative process in the food processing industry. Shockwave improved tenderness of cheap meat cuts, while the flavour was not affected, where the palatability of cheaper cuts was increased, Isabella Pittaway (2018). Ciara *et. al.* (2021) studied the effect of shockwave technology on the quality and storage stability of meat. The results revealed that shockwave showed no effect on the shelf-life of meat, while potential beef tenderness was enhanced. El-Zalaki (2022) and Gorbunova (2022) covered the use of shockwave as a promising new emerging de-

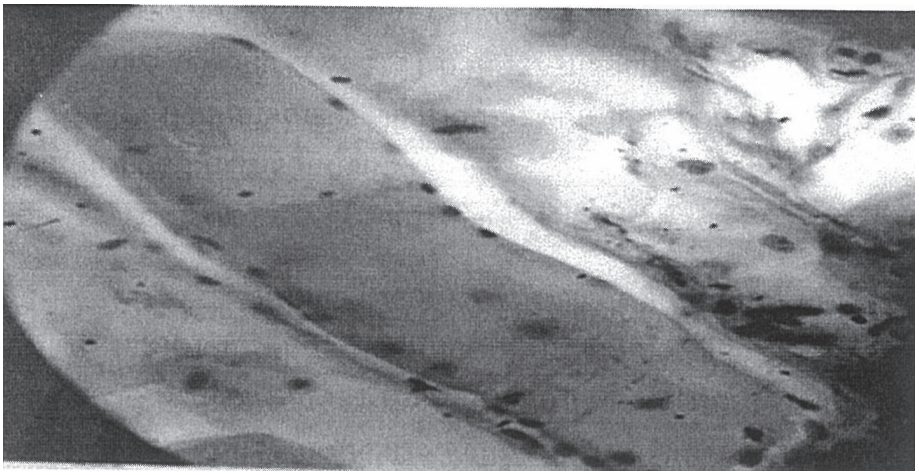

Fig. 1: Longitudinal section of *Bicepes femoris* muscle of the raw uncooked meat

Fig. 2: Enlargement of longitudinal section of papain treated raw *Bicepes femoris* muscle

Fig. 3: Longitudinal section of cooked beef *B. femoris* after papain and oryzae protease treatment

veloped technology for use to improve the quality of processed food products, one of which is meat tenderization. Further studies are recommended towards the use of shockwave in the meat industry on a commercial scale, as a low cost process with instant effect.

Mechanical Tenderization (MT)

The tenderness and flavour of meat can be improved by using sharp blades and piercing hammers. That physical process is known as mechanical tenderization (MT) which helps in the destruction of tough connective tissues, and reduction of the shear force. Use of blades for raw meat tenderization is carried out in the post-rigor stage of meat cuts. The effect of blade tenderization is the same before or after packaging and aging the meat cuts (Pietrasik & Shand 2004, Pietrasik & Shand, 2011). That process, when carried out on roasts and steaks, markedly helps to break the muscle fibers and connective tissues. MT is a simple process that can be done by retailers, restaurants, or at home. Meat mincing by using mechanical force is an easy, simple, quick, and labor saving mean of meat tenderization.

On the other hand, applying blade tenderization can reduce the intensity of flavour, affect colour of the steaks, and can result in potential microbial contamination. The equipment required for tenderizing large cuts are considered huge and relatively expensive Bekhit *et. al.* (2014a). The mechanical tenderization of meat was reviewed by Bhat *et. al.* (2018).

Tumbling (massaging)

Tumbling is also known as blade meat tenderization in the meat industry. Meat is placed in rotating drums, exposed to friction and left to fall freely. During tumbling the external surfaces of the muscle tissues are disintegrated, where the myofibrillar proteins are released. According to Pietrasik & Shand, (2004) tumbling as a mechanical means, improves both of meat tenderness and flavour.

Tender stretch and tender cuts

Hanging (stretching) the carcass under controlled cold storage avoiding cold shortening and microbial growth, can enhance meat tenderness. According to Oddvin & Kjell (2002) tender stretching carcass sides is now used, with success in many countries. Generally, some muscles of the carcass are known as tender cuts, such as the rib and loin. Such cuts after deboned and cutting of the connective tissues are considered tender and marbled meat cuts, due to the presence of intramuscular fat. On the other side, tough cuts are those of the muscles used frequently through animal's exercise, as they are rich in containing connective tissues,

The process of carcass stretching, to avoid cold shortening and meat toughness, is known as either tender stretch method or Achilles method, according to the position of the hanging hook. Emma (2019) and Jon (2019). Suspending as a mechanical process showed an effect on meat quality, Muhammed *et. al.* (2021).

The Smart Stretch TM/Smart Shape TM (4S)

The Smart Stretch TM/ Smart Shape TM (4S) system is a relatively new technology, that uses air pressure on either cold or hot-boned meat cuts for shaping them into a defined shape in a specific packaging material (Johanne *et. al.*, 2010). The 4S system shows better results with sheep meat as compared with beef, and decreases the storage pe-

riod required for ageing, Toohey *et. al.* (2013). The 4S system causes muscle stretch and prevent onset rigor contraction. and hence improves meat tenderness. The system is used on a commercial scale in Australia (Hopkins 2014).

Pi-Vac Elasto Packaging

The Pi-Vac Elasto Pack system, is another type of packaging, used on a commercial scale in Europe, to improve meat tenderness. The system involves using a wrapping material of elastic tubes with high elasticity. that is stretched under vacuum. During the process, a piece of meat is introduced inside the film. The film upon the effect of the released vacuum, exerts longitudinal force on the meat which prevents meat contraction through rigor stage (Oddvin & Kjell, 2002, Taylor & Hopkins, 2011, Hopkins. 2014). Special equipment is used for the application of this green economic system. Yet, the system is quick, non-thermal, no chilling. rooms are required, energy is also saved, and this efficient system is friendly to the environment. The system resulted in tenderness as well as a reduction in drop loss.

Ultrasonic Tenderization

Ultrasound finds its way to modify the structure and helps to tenderize meat and some other food products, as demonstrated by Sikes *et. al.* (2014), Turantas *et. al.* (2015) and Terefe (2016). Low frequency ultrasonic, was used to improve meat tenderness, with significant increase of myofibrils fragment during cold storage at 4°C (Kang *et. al.,* 2016, Kang *et. al.,* 2017, Wang *et. al.,* 2018, Zou *et. al.*, 2018).

For 24hr. Low- and high- ultrasonic frequencies showed marked effect on the chemical and micro-structure of meat proteins, enzymes, curing process, and the water holding capacity. Alma *et. al.* (2019) reviewed the meat quality as affected by ultrasound treatment, and they found that meat tenderness was improved by ultrasonic treatment.

Chemical Interventions Tenderization

Meat can be treated with various sales and organic acids as marinating agents by injecting or immersing the muscles and cuts of meat. The rapid diffusion of the marinade solutions in the meat, improved tenderness, due to the change of the rate of glycolysis, contraction, and proteolysis, as found by Lee *et. al.* (2000). This process improved meat tenderness, due to its effect on increasing the solubility of proteins as affected by the activity of protease. Different mixes containing phosphates can be formulated for use on a commercial scale, to improve not only tenderness, but also flavour, with better value of meat (Vote *et. al.* 2000, Berge *et. al.* 2001). The marinade mixes traditionally may contain salts, sugar, oils, seasonings, soy sauce, juices of fruits, vinegar, and organic acids. Naveena *et. al.* (2011) found that ammonium hydroxide changed the ultrastructure and tenderness of meat. Sorne of the ingredients of the marinade mixes, as organic acids (lactic, citric, and acetic) have an effect on enhancing meat tenderness, according to Aktas *et. al.* (2003), Kim *et. al.* (2013), and Goli *et. al.* (2014).

Cooking methods

Various dry and wet cooking methods are applicable for meat cooking. The choice of the proper cooking method depends on many main factors related to both of the meat and the consumers. Meat generally are cooked to be rare, medium, and well-done according to the meat cut and the consumers preference. Sous vide cocking of meat is a special different method, which is carried om after placing the meat cut in vacuum-sealed bag after air removal. The bag containing the meat is submerged in hot water to be tender and evenly cooked at 54°C for 1-2 hours. Baochn *et. al.* (2023) recommended that the sous vide cooking enhanced the main parameters of some bovine muscles. The best results for meat palatability are attained by the proper choice of cooking that resulted in tender, juicy, and flavoured cooked meat.

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طرق تحسين طراوة اللحوم كعامل أساسي في استساغة اللحوم: استعراض مرجعي

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يبحث المستهلكون حاليًا عن الأغذية ومنتجاتها عالية الجودة المغذية، تتمثل عوامل جودة اللحوم ومنتجاتها، التي تساعد على شرائها وتقبلها في اللون، القوام، النكهة، العصيرية، الطراوة. تعتبر خاصية الطراوة عاملًا أساسيًا من خواص تقبل اللحوم ومنتجاتها. تضمنت الطرق التقليدية والمستحدثة أعلى درجات الطراوة بما يعمل على زيادة تقبل اللحوم ومنتجاتها. درجة الحرارة، التبريد التي تتعرض لها الذبيحة أو اللحم، قبل أو بعد عملية التصلب الرُمي، تلعب دورًا كبيرًا في خاصية خشونة أو طراوة اللحم.

استخدام تقنيات حديثة خضراء، غير حرارية، موفرة للطاقة، للمساحات، للمجهود، للوقت هدف أساسي في إعداد اللحوم وتصنيعها وزيادة تقبلها واستساغتها، تحسين طراوة اللحوم تتم بعدة معاملات منها التعتيق بالتخزين المبرد، الحث الكهربي، التطرية الإنزيمية، الموجات الصوتية، الصدمات المائية القوية، الشد بطرق التعبئة الحديثة تحت التفريغ، الطرق الميكانيكية، المعاملة بالمخاليط الكيميائية. الطراوة مرتبطة بسهولة مضغ وتجزيئ اللحم والعصيرية وهي سريان السوائل خلال عملية المضغ، حيث يمثلان حجر الزاوية في تقبل المستهلك للحوم عند تناولها. ترتبط طراوة اللحوم بالتركيب النسيجي للعضلات والأنسجة اللاحمة والإنزيمات وبروتينات اللحم. تحسين الطراوة عادة ما يصاحبها تحسين العصيرية والنكهة وتقليل فاقد الطهي. على الجانب الآخر تحسين الطراوة يزيد من جودة وتسويق قطعيات اللحوم الخشنة منخفضة الجودة.