Journal of Advanced Research Design 45, Issue 1 (2018) 43-51

Journal of Advanced Research Design

Journal homepage: www.akademiabaru.com/ard.html
ISSN: 2289-7984

Application of Various Mechanical Treatments for Meat Tenderization

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ARTICLE INFO

Article history:
Received 13 February 2018
Received in revised form 4 April 2018
Accepted 6 April 2018
Available online 17 June 2018

ABSTRACT

Meat tenderness is an important quality attribute that influences consumer acceptance. The application of mechanical treatment by mean to reduce toughness of meat cuts has gained much interest recently with an intention to make use of the lower grade meat cuts. This review deliberates the function, mechanism and numerous types of mechanical work in meat tenderization. The mechanical work employs to make meat softer by loosening the muscle structure and disrupting muscle cell. Previous studies have thoroughly examined the use of mechanical treatment (such as massaging, tumbling, and grinding) as an effective meat tenderization technique. Besides that, current research on newly emerging processing technology such as high-pressure process (HPP) also shows potential to be explored. The application of mechanical work has shown impressive outcomes by reducing the shear force value that represents the hardness of meat. The present paper also described the physical, biochemical and the structural changes of the meat. Finally, the improvements in the meat tenderness by using various type of mechanical work are presented in this paper.

Keywords:
Food technology, meat tenderization, mechanical work

1. Introduction

According to FAO, the world food consumption of meat in the year 2015 was 41.3 kg per capita, and it has been projected to be 45.3 kg per capita for the year 2030. The raised interest in meat consumption forces the meat industry to provide consistent supplies of high-quality meat and meat products. Meat quality is a multi-dimensional concept that can be defined based on the nutritional, compositional quality and palatability factors [17]. Other factors such as visual appearance, smell, firmness, juiciness, tenderness and flavour also affect consumer selection. The eating quality perceived by a consumer is highly subjective. Meat tenderness is generally recognized as the most influential factor affecting the meat or meat product palatability [13]. Tender meats are more acceptable to consumers. Hence, the improvement in tenderness would increase the commercial value of the final meat product.

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Lean meat basically composed of muscle fibers. Muscle in meat consists of two main components which are myofibers and connective tissue [21]. Hence, meat tenderness is greatly affected by the structural integrity of these muscle proteins [17]. The different type of muscles showed variation in tenderness [18]. Meat tenderness is contributed by various pre-slaughtering factors such as the species, genetic, nutrition and age of the animal. Meanwhile, the post-slaughtering factors are post-mortem shortening, conditioning, processing and cooking method [21]. Previous studies found that meat tenderness is mainly associated with the structural integrity of myofibrillar and connective tissue proteins [26].

Meat tenderization is a decisive technique employed to reduce toughness of certain lower grade meat cuts or other parts. This technique would be valuable to the processor as they can supply consistently a tender product, thus satisfying consumer demands. In order to improve the tenderness of the meat, a number of tenderizing methods have been investigated, which basically involve chemical, enzymatic and physical treatments. The earlier practice of meat tenderization commonly involved an aging process by holding the whole carcass for a period of 7 to 12 days under chilled conditions depending on the meat cuts and the age [19]. The cooler conditioning leads to structural weakening of muscle protein by the endogenous proteases [12].

Technological advancement provides a great contribution to meat processing as the use of mechanical equipment to tenderize meat were evolved. There are various mechanical treatments that are applicable to the meat industry such as tumbling, massaging, grinding and injecting. These mechanical disruptions are sufficient to loosen the muscle structures, disrupt muscles cells and destroy the connection between the myofibers and the connective tissues [11]. Hence, the post-mortem processing technology employs able to improve the meat tenderness.

Meat tenderization is important to ensure the best quality of meat product. Besides that, this method can ensure the lower grade meat cuts will be fully utilized by improving its texture. It also can maximize the use of all parts of the carcass and increase the profits. These lower grade meat cuts usually used for the production of value-added meat products. Therefore, this review aimed to discuss the variety of mechanical work in meat processing and their role in meat tenderization.

2. Meat Tenderness and Factors Influence Meat Toughness

Tenderness is the most important organoleptic characteristics of meat, that defined as the toughness and resistance to cut [21]. Kerry *et al.*, [17] stated that meat tenderness is related to the strength of the structural components of the muscle fiber. Tornberg [36] elaborated that meat tenderness can be referred to the mechanical properties of meat, which involves the structural components; myofibrillar mass, sarcoplasmic proteins and connective tissue. Meat tenderness can be evaluated by instrumental methods and sensory.

Factors contribute to meat tenderness can be classified into two; pre-slaughter and post-slaughter. The pre-slaughter factors for example species, breed, age, sex, feeding and management, genetic influence and stress conditions significantly influenced the meat tenderness. Meanwhile, post-slaughter factors include postmortem glycolysis, postmortem shortening, conditioning, processing and cooking methods might contribute to the meat tenderness [21]. Kandeepan *et al.*, [16] found that spent male and spent female buffaloes had higher shear force value and muscle fiber diameter than young buffalo meat. The sensory evaluation also marked the less tenderness of meat chunks from spent male and spent female buffaloes. The specific muscles from old animals significantly tougher compared to young animals due to the strength of connective tissues and lack of endogenous enzymes capacity to tenderize the meat. As animals mature, collagen becomes more cross-linked and heat resistant and more variation in tenderness is expected. Neath *et al.*,

[25] demonstrated that water buffalo meat and beef had different in tenderness; however, the rate of tenderizing during 2, 4, 7, and 14 days postmortem did not differ significantly.

Takahashi [35] explained that meat tenderness is due to structural and biochemical properties of skeletal muscle fibers; myofibrils and intermediate filaments, and the intramuscular connective tissue; endomysium and perimysium, which are composed of collagen fibrils and fibers. Intramuscular connective tissue acts to maintain skeletal muscle fiber integrity. Hence, meat toughness could result from the properties of endomysium and perimysium. Purslow [29] also described that meat toughness is associated with the collagen content. Berry and Abraham [1] reported that the patties produced from high connective tissue trimmings exerted some influence on sensory scores of tenderness.

3. Methods to Improve Meat Tenderness

Generally, the tenderness has been accepted as a critical criterion for good quality of meat, thus any approach that serves positive impact on meat tenderness would be beneficial for further investigation. Meat tenderization is the process of reducing meat toughness of certain cuts. Meat tenderization is vital for the meat industry to ensure that lower grade meat cuts can be fully utilized, thus increase profits. Treatments to improve tenderness of round muscle would add value to the whole carcass by enabling processors to market consistently tender products, increasing returns to the processor and satisfying consumer demands.

Previous studies had reported the application of various techniques aimed to tenderize meat, which involved the use of physical forces; mechanical meat tenderizer [14], chemical; calcium chloride [8] or exogenous enzymes; papain, bromelain, ficin [32]. Methods of meat tenderization had been the subject of many studies, and the technologies keep on developing time after time.

4. Traditional Aging Method

Aging had been practised for many years and proved to be effective in tenderizing meats. Aging is the practice of storing meat beyond the normal time taken for setting and cooling to enhance tenderness [6]. Meat industry generally utilizes two type of aging; wet (vacuum) and dry aging. According to Bowker *et al.*, [4] Warner-Bratzler shear force (WBSF) value of boneless strip loins that aged for 7 days (38.1 N) and 14 days (33.3 N) at 4°C were significantly lower compared to steaks that aged for 0 day (57.0 N). However, the WBSF values of the samples aged for 7 and 14 days did not differ significantly from each other. Another study also found that WBSF value decreased significantly from 1 to 21 days of aging in all breeds (Friesien, Podolian, and Romagnola x Podolian crossbred young bulls) reaching the lowest values at 21 days [23]. The improvement in tenderness with aging was directly attributed to postmortem proteolysis. Meat tenderization happens due to structural weakening of the myofibrils, the intermediate filaments and the intramuscular connective tissue; endomysium and perimysium during post-mortem aging. The ultrastructural changes weaken the myofibers integrity in the muscle tissue [35].

However, there are some limitations to this process as this practice is very time and energy consuming. Besides that, the meat will easily spoiled and develop off-flavour when held at a higher temperature. The high processing costs and a huge area for storage at refrigerated conditions are required to implement this technique.

4. Mechanical Tenderization

In the meat industry, most of the processing involves the use of mechanical or physical force for the purpose of reducing meat particle size, softening the meat and mixing the ingredients [11]. Common mechanical treatments were tumbling, massaging, grinding and needle/blade injection. The mechanical work during the process had a significant impact on the meat quality especially textural attribute; tenderness. The mechanical work capable to alter the physical structure of muscle fibers and is effective in tenderizing meat. The application of mechanical treatment in tenderizing the meat had been reported by many researchers previously.

Tornberg [37] reported that mechanical treatment applied effectively can cause the loosening of the muscle structure, disrupting muscle cells and destroying the connection between the myofibers and the connective tissues. Tougher meat cuts usually were treated by removing the connective tissues. Apart from that, the connective tissues structure can be disrupted by blade tenderization and grinding as well. Many reports have shown that the mechanical tenderization especially the blade tenderization can significantly improve the tenderness of less tender cuts of meat. In the processing of burgers, the process of grinding is employed to reduce the particle size prior to the mixing process. Grinding process also was effective in disrupting and reducing the connective tissue of muscle fiber [39]. Physical treatments such as tumbling and massaging applied on meat also were aimed to disintegrate the muscle structure so that salt and phosphate can reach the myofibrillar proteins [5].

4.1 Massaging

Massaging usually involves a stationary drum with paddles rotating around the vertical axle. This process does not involve free falling of meat contents. Consequently, the process mainly involves muscle tissue rubbing other muscle tissue and the smooth surface of the drum. As massaging time increases, the amount of protein and fat in the exudate also increases. This effect is more pronounced in the presence of salt and phosphate. The improvement in product yield and reduction in shear force of restructured pork blocks were recorded as the massaging time increase from 6 min to 10 min [9]. In the processing of restructured meat product, tumbling and massaging are the crucial steps because these techniques help to extract salt-soluble protein thus enhance the tenderness, juiciness and slicing characteristics.

Zochowska-Kujawska *et al.*, [40] presented that massaging was effectively utilized to reduce the hardness of young and wild boars muscle. The rate of changes in textural properties and structural elements during massage is highly depended on muscle type and age of the animals. Lachowicz *et al.*, [20] demonstrated that by increasing the massaging time, it can result in a decrease of textural characteristics and the rheological parameter of the muscles. Their study also found that different type of muscles (*Biceps femoris*, *Semimembranosus*, *Quadriceps femoris*) had a different rate of changes in textural characteristics, rheological properties, and structural elements during the massage. The cause of the reduction in hardness and chewiness might be attributed to the swelling of myofibrillar protein and loosening of the connective tissue.

4.2 Tumbling

Tumbling involves the physical process of meat rotating in a drum, falling and making contact with metal walls and paddles. This process involves a transfer of kinetic energy and consequently causes alterations in muscle tissue. Tumbling usually applied for the processing of meat products such as whole-muscle or reconstituted hams. Rotating drum equipped with steel paddles inside the drum is applied to slowly move the meat pieces. This mechanical process is assisted by the addition of salt and phosphates to liberate muscular protein from the meat tissue (protein extraction).

The advantages of tumbling that mostly discuss are the formation of a protein exudate during the process. Protein exudate is a fluid that naturally expressed from muscle tissue that comprised primarily of sarcoplasmic proteins. The protein exudate acts as a sealer when the protein is denatured during thermal processing. Previous researcher has explained the relationship between muscle exudate and meat tenderness [4].

Cassidy *et al.*, [5] found that tumbling caused an increase in cell membrane disruption in both surface and deep muscle regions. Besides that, their study also outlined the effect of continuous tumbling and intermittent tumbling. They found that intermittent tumbling caused the nuclei of the hams more disorganized and the striation patterns of the hams less clear compared to continuous tumbling. This could be explained that rest period provides greater diffusion and sufficient time for salt and phosphate to exhibit the maximum effect. Once the cell membranes have been broken, the myofibrillar protein can migrate to the surface since salt and phosphate aid in solubilization. This protein exudate promotes cohesion in the cooked product.

The previous study conducted by Gao *et al.*, [7] had proved that the fresh whole pork loins (*Longissimus dorsi*) sample treated with different tumbling marination treatment; conventional static marination, vacuum continuous tumbling marination and vacuum intermittent tumbling marination significantly reduced the textural parameter of hardness compared to control samples. Besides that, tumbling treatment also resulted in higher score sensory attributes of tenderness and juiciness for pork chops. Another study also found that the decreased in shear force and the hardness value of injected roast beef (*semimembranous* muscle) that were tumbled with increases time (0, 2, and 16 hours) [28].

4.3 Grinding

Particle size reduction involves grinding, chopping, flaking, and mechanical desinewing have a great contribution to attributes of tenderness. Grinding or mechanical desinewing is the process to remove and reduce the amount of connective tissue in boneless beef shanks, plates, and chucks. Purslow [29] summarized that the toughness of meat mostly associated with the composition and distribution of intramuscular connective tissues in muscle tissues. The process of grinding capable to disrupt and reduce connective tissues link in muscle tissue thus leads to reduce in toughness.

Wells *et al.*, [39] investigated that smaller aperture size (0.19 cm) reduced the total collagen and increased the tenderness attributes of patties in contrast with larger aperture sizes (0.25cm and 0.32cm). Grinding is a common processing technique applied for tough meat cuts, especially from old cattle. Grinding process is effective to improve meat tenderness of tough meat cuts that not economically profitable for fresh consumption. Chuck and round are generally known as the tough meat cuts that always are used for the production of value-added products.

Suman and Sharma [33] found that cooking yield, pH, proximate composition and dimensional changes of buffalo meat patties prepared from difference grind size which were 3, 4 or 6 mm did not differ significantly. However, the increase in grind size caused the significant increase in shear force value. The sensory of juiciness, texture and overall acceptability were higher for patties prepared by using 3 mm grind sizes compared to 4 and 6 mm grind sizes.

Berry *et al.*, [2] demonstrated that hot-processed beef patties prepared by using 0.32 cm grind size showed significant improvement in tenderness compared to patties prepared by using 0.40 cm grind size. The sensory evaluation also indicated higher tenderness for patties produced from smaller aperture size. The smaller grind size created softness, faster sample breakdown in chewing and a greater number of smaller size chewed pieces in contrast to the larger grind size [2].

Wells *et al.*, [39] reported that the amount of connective tissue and collagen in patties were decreased by using a smaller aperture size (0.19 cm). Their research also outlined that the mechanical desinewing may remove connective tissue, but did not significantly impact on the palatability or shear force value. Mechanical desinewing operates by forcing the meat through a smaller aperture and this technique might improve tenderness attribute of beef patties. The only limitation of this technique is the major losses in the market value of minced meats compare to unprocessed meat used for fresh consumption such as steaks.

4.4 Blade and Needle Tenderization

Needle or blade tenderization is performed using a set of needles/blades that function to cuts and punctures the muscle fibers and connective tissues, and this mode of action leads to reduced meat toughness. Needle tenderization is widely applied on wholesale cuts such as steak and roasts. The previous study indicated that most of the mechanically tenderized meat cuts obtained higher sensory scores for tenderness and flavour [28]. Mechanical treatment through blade tenderization disrupted the muscle structure; disintegrated external surfaces of meat pieces and released the myofibrillar proteins, thus making this technique sufficient to tenderize tough meat cuts like round and chuck. This technique is important since it can improve the tenderness less acceptable meat cuts.

Obuz et al., [27] observed that the boneless strip loin (*Longissimus lomborum* muscle) that underwent blade tenderization resulted in lower Warner-Braztler shear force value in comparison to the control loins. However, blade tenderization treatment had higher weight loss than the control loins. The disruption of the muscle structure might allow moisture to escape from the interior of meat to the exterior easier. Narsaiah *et al.*, [24] demonstrated that the use of a handheld blade tenderizer to incise the goat meat resulted in lower shear force value compared to the controls.

Pietrasik and Shand [28] investigated the influence of blade tenderization prior to injection on beef roasts and reported that it can be effectively utilized to reduce the shear force and hardness of *semimembranosus* muscles. Their study indicated that the mechanical tenderizer causes sufficient disruption of the muscle fibers and connective tissue to reduce shear force values. Hayward *et al.*, [10], reported that blade-tenderizer significantly reduced the shear force of beef *longissimus* steaks in contrast with control samples. It can be explained that the tenderness improved because of the decreased in the structural strength of both myofibrillar and connective components. Based on the study conducted by Seideman *et al.*, [30], blade tenderization significantly reduced the shear force, detectable connective tissues and increased rating for tenderness of both *semitendinosus* and *psoas major* muscles. The blade incision of blade tenderization method is the cause for the disruption of connective tissue, which increases the muscle tenderness.

There were some limitations with this technique as mechanical disruption caused potential microbial cross-contamination and colour changes in the penetration area. The needle tenderizer in a large-scale plant usually is huge and expensive. Previous studies also highlight that blade tenderization caused higher drip loss and reduced shelf life.

5. High-Pressure Processing (HPP)

According to Bolumar *et al.*, [3], the HPP effect is due to the disruptive nature induced by the pressure that causes dissociation of the myofibrillar proteins. There are many researchers had reported the effectiveness of high-pressure processing for meat tenderizing. The tenderizing effect was understandably due to the structural changes of the myofibrils by the high pressure. Sikes *et al.*, [31] reported that the HPP-heat treated samples would be juicier and more succulent than the heat-only samples. Combination of pressure and heat treatment resulted in a significant reduction in the toughness of the meat. They demonstrated that beef steaks heated at specified temperatures and combined with pressure at 200 MPa had lower peak shear force in contrast with heat-only samples. This could explain why the HPP-heat treated meat was tenderer than heat-only treated samples.

Ma *et al.*, [22] observed that the hardness of post rigor beef *longissimus dorsi* was largely decreased when heated at 200 MPa pressure and higher temperature (60°C and 70°C). Meanwhile, there were no significant changes in hardness of beef samples when the pressure applied at ambient temperature (20°C). Hence, it can be suggested that treatment of pressure alone without manipulating the temperature did not affect tenderness. Jung *et al.*, [15] reported that high-pressure treatment at low temperature (10°C) contributed to the tenderness of bovine muscle (*Biceps femoris*). The improvement in tenderness attributed to the ultrastructural changes examined through electron micrographs. The samples showed contracted sarcomeres with structural smoothness but disorganization of thick and thin filaments after treatment at 325 MPa. The ultrastructural changes are highly depended on the intensity of the pressure.

The previous study conducted by Ueno *et al.*, [38], found that the smooth surface associated with the disappearance of the wavy structure was observed in the sample pressurized at 100 MPa, and these changes increased with increasing pressure (200 MPa, 300MPa and 400MPa) applied to the muscle. The deformation of the honeycomb-like structure of endomysium was accelerated with the increase of pressure applied to muscle samples. The structural changes of intramuscular connective tissue by high pressure exert a significant effect on tenderness. Sun *et al.*, [34] outlined that high pressure can modify the structure and function of proteins. The structural changes will affect the texture of the muscle. Simultaneous application of pressure and heat to meat has been shown to improve tenderness but still, the effectiveness is depending on the temperatures and pressures used.

From the compilation of the previous studies, it can be summarized that the application of high pressure to improve meat tenderness showed great potential. The condition for treatment such as pressure and temperature need to be understood so that they can be optimized. The problem associated with the application of HPP on meats usually are the changes in colour due to muscle protein denaturalization at the pressure required for meat tenderization. According to consumer perspective, the HPP-treated meat is less accepted as fresh meat. Besides that, the application of HPP requires a high initial investment. Thus, these techniques less familiar in industrial scale for meat tenderization for the time being.

6. Conclusion

As the conclusion, there are various mechanical treatments available for meat tenderization. The effectiveness of each technique varies depending on the type of muscle. The technology advancement contributes to the improvement of the methods. The use of technology combined with mechanical treatment will provide a greater effect on meat tenderizing.

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