International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

Current Development on Meat Tenderization

Divyani Madarkar

Food science and Technology School of Biotechnology and Bioinformatics D Y Patil deemed to be university Navi Mumbai

Abstract: ***An important quality parameter of meat determining consumer acceptance and price is meat tenderness. Industry might use different methods to improve meat tenderness each with its advantages and drawbacks. The present paper describes after slaughter and before slaughter technique implemented in meat tenderization. It includes methods like high pressure processing, shockwave electric methods, ultrasound, electrical stimulation etc. Comparison of these methods help us to understand the best method for meat tenderization. To measure the tenderness of pre-rigor different methods are used and at the time of slaughter to monitor changes in tenderness during rigor during post mortem aging and rigor development.***

Keywords: Meat, tenderization, rigor mortis, electrical stimulation

1. Introduction

Meat is basically build up of muscle fibers bound together by protein filaments . Tenderizing meat it defined as fragmentation the long strands of muscle and softening the collagen til it turns into gelatin. It is an important palatability trait. Meat is animal flesh and worldwide eaten as a food (Kumar, Prasad, & Kumar, 2018) The demand for meat specifically red meat is increasing day by day. But the most important factors they consider are tenderness, juiciness, flavor and sensory attributes (Bhat, Morton, Mason, & Bekhit, 2018). A complex problem in meat quality which cover several factors of variation such as genetics, transportation ,handling of animals during production and slaughter and also the processing of meat during product processing.(Remignon, Molette, …, & 2006, n.d.)

A large amount of variation in meat tenderness occurs under current production and postmortem handling system. Tenderizing meat allows to serve protein rich meals.(B C Bowker, Fahrenholz, Paroczay, & Eastridge, 2007).Tenderness is the most important factor for the consumer in determining eating quality of meat. Complaints about tough meat and variation in meat tenderness are a general worry to the meat industry world-wide, especially for beef (Sørheim & Hildrum, 2002). Different methods can be used by the meat industry to improve meat tenderness each with its advantages and drawbacks. Tenderization of meat during post-mortem ageing is caused by the structural weakening of myofibrils, desmin intermediate-fila- ments and the intramuscular connective tissue(K. Takahashi, 1999)

The application of hydrodynamic pressure or shockwaves has showed outstanding enhancements by reducing the Warner Bratzler Shear Force by 25% or more than 25%. Shockwave technology applied to meat tenderization shown a low-cost and non-invasive technique which has no negative impact on the microbiological and chemical product stability. However, commercial application is not available since limitations such as damage in packaging material after shockwave treatment, efficient shockwave delivery in an industrial resistant prototype, and effective parameters(Bolumar, Enneking, Toepfl, & Heinz, 2013).

Another method is high pressure processing useful for pasteurization food while maintaining quality of fresh food. Pressure greater than 400MPa is generally necessary to achieve microbial contamination. This method when combined with papain enzyme treatment improves meat tenderness(Simonin, Duranton, & de Lamballerie, 2012).Tenderness improvement can be achieved by applying various post-mortem treatments involving ageing, using enzymes, mechanical tenderization methods and electrical stimulation(Biswas, Das, Banerjee, & Sharma, 2007)

Results of these experiments suggest that electrical stimulation will accelerate postmortem pH decline, hasten rigor development and improve certain palatability characteristics, especially tenderness(Stimulation, 1981).

Methods used to improve meat tenderization

Technologies	Cost	Level of technical inputs	Energy Consumption with respect to time	Adoption by Industry	Tenderizing effect	reference
Hydrodynamic-pressure Processing		↑	Less energy consumes less time is needed	↓	↑	(Solomon et al., 2007) (Liu et al., n.d.)
High-pressure processing	↑	↑	More energy consumes less time is needed	↓	↑	(Brian C Bowker, Schaefer, Grapperhaus, & Solomon, 2011) (Suzuki, Watanabe, Iwamura, & Ikeuchi, 2014)
Ultrasound	↑	↑	More energy consumes less time is needed	↓	↑	(Dickens, Lyon, & Wilson, 1990)
Pulsed electric field	↑	↑	Less energy consumes less time is needed	↓	↑	(Reviews & Science, 2010)
Marination/ Infusion/ Injection	↓	↓	Less energy consumes more time is needed	↓	↑	(Kauffman, 1987)
Electrical stimulation	↓	↓	Less energy consumes less	↑	↑	(K. Takahashi, 1996)

			time is needed			
Aging	↓	↓	More energy consumes more time is needed	↑	↑	(Got et al., 1999)

Significance: ↑ = High
↓ = Low

Hydrodynamic-pressure processing:
In the last two decades, the high pressure processing to food systems particularly ultra-high pressures (>100 MPa) has received much attention by the scientific community and as a consequence commercial installation have come true (Bajovic, Bolumar, & Heinz, 2012). The fact is that high pressure processing gives high potential that is difficult to achieve by common processes in the development of novel and future optimized food applications.

Hydrodynamic pressure almost yeild 10% to 70% reduction in shear force which was depending upon certain factors like, rigor stage, aging time, muscle-fiber orientation, treatment conditions, animal species and muscles and background toughness (Solomon, Liu, Patel, Paroczay, & Eastridge, 2004; 2008; 2011; Zuckerman,Bowker,Eastridge,&Solomon,2013;Bolumaretal. , 2014).

Despite hydrodynamic pressure processing could produce remarkable improvements in the tenderness of the meat with respect to low cost, no commercial application of this technology and further research is required to overcome the existing limitations, such as development of an industrial size continuous system with a consistent shockwave delivery as well as prevention of packaging damage during processing (Bolumar & Toepfl, 2016).

HDP has repeatedly been shown to tenderize a variety of meat products (Solomon et al. 1998; Moeller et al. 1999; Claus et al. 2001; Marriott et al. 2001),then too the mechanism of tenderization is not well understood. There is a lack of data showing the tenderization effect of combining HDP with aging treatments, and their influence on muscle proteins related to meat quality. Thus, the table below was the result of the study carried on to determine the influence of HDP and aging on the tenderness and myofibrillar protein characteristics of fresh, boneless beef strip loins.

Parameter	Treatment	Aging	period	(days)	SEM	P value		
		0	5	8		Treatment	Ageing	Treatment x Ageing
MFI	Control HDP	69.2d 86.7c	102.5bc 117.ab	116.7ab 128.0a	7.8	<0.01	<0.0001	NS
MSP	Control HDP	15.9c 133.6c	127.3c 134.4b	135.7b 144.8a	3.4	<0.0001	<0.05	NS
TPS	Control HDP	193.0c 200.3ab	191.2bc 205.2a	196.2bc 205.2a	3.3	<0.01	NS	NS
pH	Control HDP	5.44 5.50	5.49 5.51	5.49 5.51	0.02	NS	NS	NS

Effects of HDP and aging treatments on the electrophoretic profile of myofibrils isolated from beef strip loins
Myofibrillar Fragmentation Index (MFI), protein solubility & pH values of control & Hydrodynamic pressure (HDP) Beef strip lion treated at 48 hours postmortem & then aged 0, & 8 days

NS indicates not significant ($P > 0.05$). a–d Least square means across all aging periods and treatments with different superscripts differ significantly ($P < 0.05$). SEM, standard error of means; MFI, myofibrillar fragmentation index; MPS, myofibrillar protein solubility (mg protein/g muscle tissue); TPS, total protein solubility (mg protein/g muscle tissue).(B C Bowker et al., 2007)

Ultrasound technology
Postharvest treatment of fresh cut meat with technique such as Hydrodynamic shockwaves enhances its tenderness without compromising any microbial and chemical stability (Bolumar, Bindrich, Toep, Toldrá, & Heinz, 2014). Ultrasound also offers potential as a tenderizing treatment in meat as it can be applied without causing the changes in appearance that occur with some other treatments(Edition, n.d.) The ultrasound conditions used to treat meat vary widely, and correspondingly the effectiveness of ultrasound for meat tenderization varies. Studies shows that tenderizing effect depends on intensity of ultrasound treatment usually low intensity (2 W/cm2) produces little effect, even though the samples received extended exposure (up to 70 min)(J. G. Lyng, Allen, & McKenna, 1997)(Pohlman, Dikeman, Science, & 1997, n.d.)

Muscle samples	Frequency (Khz)	Power input (W)	Treatment time	Tenderness effect	References
Holstein bulls Longissimus lumborum	20	100 , 300	10 , 20, 30 min	When the treatment of ultrasonic power of 100 W was combined with papain enzyme for 20 min , highest tenderness was obtained	(Barekat & Soltanizadeh, 2017)
Longissimus lumborum et thoracis and Semitendinosus muscles Uncooked beef samples	24	12W/cm^2	4 min	ultrasound treatment using high power intensity was able to reduce other parameters without much effect on tenderization	(Jayasooriya, Torley, D'Arcy, & Bhandari, 2007)
beef Longissimus thoracis et lumborum and Semimembranosus muscles	20	62W/cm^2	15 sec at intervals for 14 days	Not significant effect on tenderness of meat	(James G. Lyng, Allen, & McKenna, 1998)
Semitendinosis muscle	25.9	-	0, 2, 4, 8, 16 minutes	high intensity ultrasound was capable of tenderizing meat	(Smith, Cannon, Novakofski, McKeith, & O'Brien, 1991)

Broiler breast muscles	40	2400	15 min	Post moterm ultrasound treated muscles showed low shear values	(Dickens et al., 1990)

Shockwave electric method

This invention relates to meat processing. In particular, this invention relates to a method and System for tenderizing and Sterilizing meat using electro-mechanical transducers to project opposing planar Shock waves in meat.

The early deboned postrigor chicken breasts were exposed to two levels of electrically produced hydrodynamic shockwaves. Electrically produced shockwave process have potential to provide chicken processors with the ability to early debone and produce tender breasts to enhance tenderness(Claus et al., 2001)

This invention relates to meat processing. In particular, this invention relates to a method and System for tenderizing and Sterilizing meat using electro-mechanical transducers to project opposing planar Shock waves in meat. Meat sterilized and tenderized by Shock waves like pressure pulses(Patent, 2010)

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A shockwave is the instantaneous development of pressure waves that travel through material with an acoustical match to water as in meat. Pressure in meat induces a tenderization effect which is likely due to dissipation of mechanical stress at the boundaries of acoustic impedances. The tenderness was measured using the Warner–Bratzler shear force (WBSF) procedure(Bolumar et al., 2014)

Tenderness improvement by hydrodynamic shockwave treatment(Bolumar et al., 2013)

Meat	Shockwave produced by	Tenderness improvement
Beef	Explosives	68%
Pork	Explosives	17%
Lamb	Explosives	36-67%
Turkey	Electrical discharge	13%
Chicken	Electrical discharge	42%

The tenderizing effects of treating beef loins with shockwaves was estimated. Samples were treated as either intact loin or steaks roasts on first day and Warner–Bratzler shear force (WBSF) was measured on seventh day with the sparker head above the samples, non-aged steaks with 80 pulses at two locations had lower WBSF than controls. In both sparker treated and control steaks, WBSF decreased from first day to seventh day. The improvements in tenderness averaged only 5–10% on day first, with a maximum tenderness improvement of 24%(Brian C Bowker et al., 2011)

Enzymes

Enzyme mediated degradation of muscle protein helps to improve tenderization. Plant and microbial origin enzymes that are exogenous in nature are used (Bhat et al., 2018). Exogenous enzymes can degrade both myofibrillar and connective tissue proteins. Of the techniques identifed as having a fantastic effect on tenderness, the very best and oldest is postmortem cooler growing older. It is constructed from 3 primary additives, μ-calpain, m-calpain and calpastatin (Calkins & Sullivan, 2007). The full-size degradation to both myofbrillar and collagen proteins is as a result of papain enzyme. Alkaline elastase specifcally degrades collagen and elastin. Little degradation of myofbrillar protein outcomes in less tenderizing impact however additionally lowering the opportunity of over-tenderizing(Ashie, Sorensen, & Nielsen, 2002) As a self-proscribing enzyme, some constrained degradation can enhance tenderness with out the risk of a mushy or mealy texture(Takagi,et al). A large boom in tenderness became observed whilst an enzyme answer was injected into muscle versus dipping or tumbling in brine(Wang, 1919). Later on, proteolysis of muscle proteins was proposed and has since been considered as the primary mechanism of meat tenderization(OUALI, 1990)

Electrical stimulation

The combined muscle tensioning and electrical stimulation treatment increment the percentage of fillets harvested at1 h post-mortem which was considered tender in large amount than the regular ones(BIRKHOLD, JANKY, & SAMS, 2012).

Electrical stimulation of-pre-rigor muscle has comes considerable attention recently as a means to enlarge tenderness or alleviate the outcome of cold shortening("Effects of Electrical Stimulation on Meat Tissue and Muscle Properties-a Review," 1979). It is found that electrical stimulation increases colour and also lean structure of meat("Tenderness Improvement of the Major Muscles of the Beef Carcass by Electrical Stimulation," 1981). After doing electrical stimulation it accelerated the rate of glycolysis and also enhanced enzymatic activity("Effect of low voltage electrical stimulation and temperature conditioning on postmortem changes in glycolysis and calpains activities of Korean native cattle (Hanwoo)," 2001). Hence we can say that electrical stimulation when combined with exogenous enzyme treatment we get better tenderization effect. Sometimes seen that effect of electrical stimulation on tenderness improvement was not compatible throughout the carcass(Savell et al., 1977). Results of these experiments suggest that electrical stimulation will accelerate postmortem pH drop-off , hasten rigor development and improve certain satisfactory characteristics, especially tenderness(Stimulation, 1981)

The low frequency technique coupled with a mild or delayed chill routine exhibited significant tenderizing effect relative to that observed in unstimulated control meat (2 Hz, 500V)(G. Takahashi, Lochnert, & Marsh, 1984)

Method Description	Efficiency	Reference
Low shear values 820 V,340 mA) for either 0,15,45, or 75 s	Less but consistent tenderization	(BIRKHOLD et al., 2012)
Electrical stimulation of (440 V, 2 s and 1 s)	ordinary tenderisation	(Jonas, 1992)
Five groups (T1, T2, T3, T4 and T5) were treated with variable voltages of 35, 110, 330, 550, 1100 with fixed 50 Hz and 10 pulses/s for a duration of 3 min	Microbiologically more stable According to sensory panel more tender than the control meat	(Biswas et al., 2007)
Electrical stimulation(100V) significantlytenderized breast muscle when deboned and also decreased sarcomere length	Less tenderization	(Froning & Uijttenboogaart, 2012)
Electrical stimulation of 350 to 500 mA induced forceful contractions that led to torn myofilaments	Tenderization observed	(Sams, 1999)

High pressure processing

When freezing at low temperature combined with high pressure method it helps to inhibit the disadvanatges of only pressure application method in terms of moisture, force, color, microbial quality and stability of fresh beef samples(Fernández et al., 2007). The pressure application on proteins leads modification in protein structure. As a basic mechanism, the pressure application induces unfolding in structure of protein, subsequent folding after release of pressure which leads totenderization of meat.

Slices of partially cured pork, packaged in pouches under vacuum were subjected to 250 MPa for 3 hr at 20°C in a 15-litre pressure vessel. This process induced faster (3 hr instead of 2weeks) curing and tenderisation, and to improve water retention(Carlez, Veciana-Nogues, & Cheftel, 1995).

HPP can either be applied at ambient or low temperatures, or at high temperatures. Temperature denatured protein has a tendency to aggregate and the aggregate remains stable after cooling. Whereas pressure favours dissociation and unfolding of proteins, with refolding and re-association once the pressure is removed(Warner et al., 2017) We can say that there is not much research happened on this method with aspect to meat tenderization. Mostly high pressure processing is used for fresh made foods and it only decreases he microbial count or helps in discolouration loss.

2. Conclusion

Technological interventions like electric stimulation, suspension techniques,use of exogenous enzymes, and getting old which are currently carried out inside the meat industry are effective in enhancing tenderness. However, there are some barriers and downsides of the usage of those strategies. Emerging tenderization strategies like hydrodynamic-strain processing, HPP, PEF, ultrasound, system provide some benefits over the implemented methods, however, would require initial capital investments and adjustments in the meat plant design. High stress processing, shockwave processing, ultrasound, pulsed electric area may be used to boom the tenderness, predominantly through bodily disruption to muscle shape, enhanced proteolysis and aging and muscle protein denaturation and solubilisation relying on the era. We can say that methods like hydrodynamic pressure processing, pulse electric method, enzymes and electrical stimulation consumes less energy compared to ultrasound and electrical shockwave treatment methods. In terms of cost effective we could say enzyme treatment and electrical stimulation are more cost effective than the other methods. Further, extra research is required to optimize the procedure parameters for distinct muscle groups and cuts before a number of these novel strategies should find industrial utility within the meat industry.

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