Review Article

Relation of Electrical Stimulation to Meat Standard

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Abstract | The influence of electrical stimulation to enhance meat excellence and efficacy of meat processing is discussed. Mechanism involved in it is to increase the rate of postmortem glycolysis resulting in somatic, biological and on tissue level alterations. Electrical stimulation fastens the propagation and termination of rigor mortis hence decreasing the processing time and fatigue. After electrical stimulation, the muscles become paralyzed and the rigor mortis is dispatched to reduce the time spent in the muscle and his fatigue. It is also found to enhance meat tenderness and to boost meat sensory attributes. But it may also have adverse effects on some meat quality characteristics like holding capacity of water and other one is color. To get the desirable effects from electrical stimulation, it should adequately along with other methods. In spite of a wide exploration and study on electrical stimulation, the fact that it has been explored and investigated thoroughly in a number of countries around the world. It is currently applied properly on commercial scale in few countries. It has different impact on different type of muscles, so basic know how of changes occurring when it is applied to different kind of muscles should be known to get maximum benefits from this technology.

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Introduction

Improvements in technology have effect the meat quality. Meat industry started to prefer consumer demands. Changing patterns in the meat sector are key factors driving multiple measures to enhance or preserve commodity consistency. The meat industry has recently transformed from commodity based to consumer-lead (Troy, 2006). Consumer demand for: Convenience, health, safety, taste, uniformity, good appearance, nutritive value, variety of meat and meat products.to satisfy consumer there is a need to work on new methods of developing products and in research sector (Troy and Kerry, 2010). In meat industry after slaughtering the animal, to improve meat quality, carcass electrical stimulation (ES) is done, a method in which an electric current is passed through slaughtered animal. In meat producing animals, the aim of the meat scientists is to accelerate the rigor mortis process, a series of biochemical reactions that occur after death. Early tissue experiments revealed that rigor growth was improved by ante-mortem tension or electrical stimulation, or by sustaining elevated carcass temperature (Chrystall and Devine, 1985). Approximately 159,000 tons of total red meat production was obtained from livestock that were slaughtered during 2010. The report shows a 20% portion of the total production comes from sheep and goat meat (Cetin et al., 2012).

During postmortem glycolysis, rigor is developed in muscles followed by physical and chemical changes. Changes in any of these processes can change meat characteristics. ES is very important to improve meat quality and sensory attributes. Before animal is exsanguinated, there must be optimum level of muscle glycogen to get maximum efficacy of ES. Studies made by (Dutson et al., 1980) on stressed anti mortem beef proved that ES has no effect on: Postmortem pH, color, tenderness, and sensory properties. Transportation tension also results in glycogen levels loss, which results in a higher pH of the beef, reduced tenderness, water-holding ability and loss of color appeal (Kadim et al., 2014). Controversies still present on the topic of effect of ES on meat quality. Some authors reported positive effects (Cetin et al., 2012). Other reported no effect (Botha et al., 2009; Kim et al., 2013) and in some cases hazardous effect (den Hertog-Meischke et al., 1997; Simmons et al., 2008) of ES on meat quality.

History

In 1749, Benjamin Franklin tenderized flesh of turkey by applying ES (Lawrie and Ledward, 2014). Some research work had been made on ES in U.S during the late 19th century, but these studies were of no use (Mota-Rojas et al., 2012). Successful experiment of ES was done in 1950's (Birkhold and Sams, 1993). (Carse, 1973) work showed that main role of ES is to increase the rate of postmortem glycolysis and to reduce the postmortem pH. (Taylor and Martoccia, 1995; McKenna et al., 2003) ES was declared as a method to enhance organoleptic properties of meat such as: color, flavor, tenderness, and odor.

Types of ES

ES has three types, extra low voltage electrical stimulation (ELVES), low voltage electrical stimulation (LVES), high voltage electrical stimulation (HVES).

Extra low voltage electrical stimulation

Involves the voltage less than 100 V.

Low voltage electrical stimulation

Include voltage between 100-110 V. Also called as medium voltage electrical stimulation.

High voltage electrical stimulation

Include voltage greater than 110 V, mostly HVES and LVES are discussed in literature. Major difference exists in: Amperage, Impulse frequency, Kind of electrode, Total time, Duration between slaughtering and stimulation. Conflicts in reports on ES efficacy occur due to above mentioned factors. Variation in studies may also due to: Age of animal, Kind, Management, and Handling. Efficacy of ES depends upon following factors regardless of which voltage is used: Cost, Species, Slaughtering place management and handling and Rate of production.

Merits of LVES

It is applied before 10-20 min of bleeding. Not very costly and safer (Bendall et al., 1976).

Demerits

Labor effective and less effective than HVES (500-1000 V or more).

Merits of HVES

It gives delay time of 60 min before ES is applied.

Demerits

Overall great investment is required. Precautionary measures should have adopted (Hwang and Thompson, 2001) showed that tenderness of meat is increased by increasing delay time between slaughtering and stimulation. According to authors it is due to the decrease in calpain activity simultaneously after slaughtering. On the other hand, stated that effect of bovine on ES lowers after fifty minutes of slaughtering. So, authors recommended ES thirty min after bleeding. But now a days practices are made without providing this delay time, because it helps in proper bleeding and increase tenderness of meat. (McKeith et al., 1981) did a comparison about the efficacy of HVES and LVES on different time duration. ES was done at 150 V or 550 V (1-2 min) at sixteen pulses per min with a break of 1.8 sec in between and correlate it with non-stimulated ones. It was showed that HVES for shorter time gave brighter color, enhance meat tenderness and flavor in comparison to LVES. (Roeber et al., 2000) reported that time period and strength of impulses (ES) has an effect on meat color and tenderness. Beef carcass was divided into two, one half was stimulated at (HV) 300 V while the other half of carcasses was stimulated with (MV) 100V. Long duration (16 cps) and Medium duration (11 cps) were also compared.

It was concluded that electrically stimulated meat was more tender and brighter in color than non-stimulated one. According to (Morton and Newbold, 1982) ATP value in sheep lowered to half of its initial value in time of about twenty min, two to three hours and five to six hours in HVES (240 V, 10 ms , 50 Hz) LVES (45 V, 10 ms, 50 Hz) and controlled carcasses.

Practical application of ES

Instead of how to enhance meat excellence, ES is also being implied for other objectives. In slaughterhouses of countries mainly of Australia and New Zeeland, ES is carried out instantly after stunning before slaughtering, instantly after slaughter/ during de- hiding. It is applied after stunning prior to slaughtering to avoid the movement of rear legs for worker's safety.ES is applied after slaughtering to enhance efficacy of bleeding out (Craig et al., 1999). By this process (LVES), muscle ATP decreases that enhance the tenderness by reducing the capacity of muscle shrinkage during freezing. To avoid spinal cord damage, ES is applied before de-hiding. But all types of ES should avoid to inhibit hardening of muscles due to high temperature and lower pH that could happen during pre-rigor.

Lawrie and Ledward (2014) to enhance ES efficiency slaughterhouses should work on how to improve meat quality through packaging. For this purpose, prepackaging of meat cuts is before ES. To lower the exudative and drying rate/loss of carcass, these are vacuum packaged after de-boning of hot cuts. ES is useful to avoid cold shortening in carcass. As compared to whole carcass, meat cuts are easy to stimulate. Due to large surface area of cuts, they have fast cooling rate than whole carcass. Microbial growth depends on cooling rate, increased cooling rate suppresses microbial growth rate. So meat cuts have less tendency to microbial load than whole carcass. Although, cold shortening is prevented, but this procedure lowers ES efficacy and increase the factors required for meat conditioning. This can be controlled by keeping cuts in cold storage instantly after their removal from hot carcass. And this depends upon muscle type and their behavior towards ES and conditioning. Cooling rate also differs according to type of muscle. Muscles near to carcass upper/outer surface are readily cold than inner muscles due to less depth. So, it is concluded that efficiency of ES is affected by time period and type of cold storage.

Wiklund et al. (2001), applied the same method to red meat and found that damage to meat due to cold shrinkage get lowers and increase the efficacy of ES but with the passage of time during cold storage, softening response of ES get decreased at -1.5 °C. Hence it was reported that ES has negative effect on commodities stored at lower temperatures for long duration. Koohmaraie (1996), reported that hot deboning is done at 30-40 °C (tropical areas), causing the damage or removal of muscles during early stages of rigor mortis, resulting in shrinkage and hardness. It can be prevented by applying ES. Babiker and Lawrie (1983) experimented that bovine *Longissimus dorsi* M. at 30-40 °C has more tenderness than non-stimulated ones. A comparison was made at 30 and 40 °C that showed a clear decrease in water holding capacity and increased microbial load in carcass at 40 °C with less tenderization by ES. This showed that protein denaturation can be prohibited by controlled application of temperature causing damage only to enzymes responsible for proteolysis.

Effect of ES on postmortem glycolysis

Hwang et al. (2003); Simmons et al. (2008) mechanism of ES includes the postmortem glycolysis resulting a decrease in postmortem pH due to reduction in muscle glycogen. Simmons et al. (2008) by applying ES vast shrinkage of skeletal muscles occur that is prevented by elongation of fibers. Hwang et al. (2003) physical damage to myofibrillar matrix initiates proteolysis. Two most important changes due to ES includes initiation of rigor mortis by glycolysis and decrease in pH value < 6.4. (Suhre, 1983) rate of rigor mortis increases with availability of ES and decreases with its unavailability. In addition to this, ES also prevents thaw rigor in hot meat cuts frozen before initiation of rigor mortis. So, ES helps in preventing cold shrinkage that is due to decrease in temperature. (Cross, 1979) listed factors that cause tenderizing effect of ES. One of those is rapid decrease in ATP that lowers the chances of cold shrinkage and reduction in postmortem pH due to high temperatures (30-32°C) resulting in an increased efficiency of proteolytic enzymes.

The biochemical and physiological basis of ES

ES initiates the postmortem glycolysis that results in pH depletion due to reduction in muscle glycogen (Hwang et al., 2003; Simmons et al., 2008). Physiological action of ES involves discharge of calcium ions (Ca^{2}+), from sarcoplasmic reticulum to enhance tenderness. Myosin ATPase influence muscle contraction and because of this contraction, released Ca^2+ initiates calpain and interferes Z-line (Warriss, 2001; Mota-Rojas *et al.*, 2012). All of this occurs at a pH 6.5 and temperature of 30°C (Warriss, 2001; Mota-Rojas *et al.*, 2012). This state cause strong calpain action. Lysosomal body get disturbed causing discharge of cathepsins, that increase muscle proteolysis (Warriss, 2001). Cold shortening occur when hot carcasses are exposed to cold storage (10°C-15°C) without releasing body heat. In response to this calcium ion pump release excessive Ca^2+ hence increasing amount of myosin ATPase. Large amount of ATP is present now for excessive muscle shrinkage causing meat hardening (Warriss, 2001). This get worse by thaw rigor at temperature < -10°C, in meat before rigor mortis (Lawrie and Ledward, 2014).

Under this situation, ATP is available in larger quantities, however calcium ion pump gets disintegrated at temperatures below -10°C, and calcium ions are still present in sarcoplasm. And when this carcass is thawed in the presence of larger amounts of ATP, excessive muscle contraction occurs. In Australia and New Zeeland, carcass is subjected to low voltage electrical stimulation instantly after exsanguination to produce tender meat. Reason behind this is the LVES reduced ATP amount hence rendering muscle contraction. So, by using ES, frozen storage time can be reduced and so is the ATP amount. (Lawrie and Ledward, 2014) muscle can be shorten to 30% of its natural length due to thaw rigor. However, because it is fixed to skeleton so more shortening is prohibited. The availability of ATP causes contractile proteins polymerization of: actin and myosin into actomyosin. Protein polymerization can be determine by loss of sarcomere length, causing muscle hardening. During initial stages of rigor mortis, adenosine tri-phosphate (ATP) converts into adenosine di-phosphate (ADP), that is further reduced into ionosinmonophosphate (IMP) (King *et al.*, 2004). Due to this chemical reaction, there is a continuous reduction in energy required for protein polymerization. Hence rigor mortis reduces ATP reserves. ES reduces the amount of available ATP, hence there is no more energy present for protein polymerization so muscle contraction is prohibited producing softer meat (King *et al.*, 2004).

(Kang *et al.*, 1991) studied the effect of ES (50 mA) in rabbit muscle. According to hims research, actin and myosin polymerized to form actomyosin during contraction of muscle. There were clear changes in myofibrillar proteins. Actomyosin complex is dragged into the mermyosin fraction of main myosin helix. However, ATP is available in mermyosin that causes the release of actin and myosin from actomyosin complex. Hence, resulting in relaxation of muscle. Reduction in ATPase action observed during initial stages of ES but it increased gradually during storage. Hence, it was established that alterations in actomyosin were reduced by applying ES.

Response variations in muscle to electrical stimulation

With respect to their biochemical behavior muscles vary, so different types of muscles vary in their behavior to cold shortening and conditioning. These variations in muscles behavior are due to intrinsic characteristics of muscle fibers, of which muscles are made of. Muscle fibers vary in size, densities, physiological and biochemical characteristics hence producing different types of muscles. Categorization of muscles is done on color basis (white and red). But muscle fibers are not evidently white or red in color but contain a heterogeneous mix of these tow colors. This heterogeneous mix gives each muscle different characteristics and hence different behaviors to ES. This could oppose effect of ES in meat quality enhancement. (Lawrie and Ledward, 2014) suggested that rate of phosphate generation is more in white muscle during postmortem glycolysis as compared to red. Absence of cold shortening in white muscle is due to the production of higher amounts of inorganic phosphate during initial postmortem stage. (Buege and Marsh, 1975) stated that on storing pre-rigor red meat in excess of Oxygen below 15 °C prevent cold shortening. This can be stopped by using chemicals that stop further consumption of oxygen required to reproduce ATP. According to authors, at low temperature, cold shortening occurs when Ca^2+ is released in excessive amounts during postmortem anaerobic conditions and sarcotubulor system failed to reabsorb Ca^2+.

ES enhance tenderness by preventing cold shortening (Cross, 1979; Bouton *et al.*, 1980; Mota-Rojas *et al.*, 2012). ES has more influence on white muscles but cold shortening has less effect on these muscles. On the other hand, cold shortening has more influence on red muscles because they are affected less by cold shortening (Devine *et al.*, 1984) in acidic conditions and in vivo temperature, water losses by pork (PSE) are higher than in beef due to ES. den Hertog-Meischke et al. (1997), suggested that a quick reduction in pH causes the loss of water holding capacity in beef. And the rate of water holding capacity reduction depends upon rate of chilling. In pork, quick reduction in pH causes the intracellular osmotic pressure to allow the loss of water holding capacity by muscles. This confirms the point of (Henderson et al., 1970) that there are more changes due to conditioning in pork than beef, causing the increase in osmotic pressure in pork. This may occur due to more protein denaturation in pork muscles than in beef. Lawrie and Ledward (2014) reported that white muscles have more tendency to denaturation than red muscles. George et al. (1980) sarcolemma of pork allows more water penetration than that of beef. Hence, ES enhance exudation to 4-5 times in pork (Gigiel and James, 1984).

Effect of ES on meat eating quality

Meat eating quality is detected by organoleptic properties. Industrialist will be at lost if not fulfilling consumer requirements. Organoleptic qualities are affected by a lot of features before and after slaughtering. Meat quality can be enhanced by modifications in these qualities. ES is used to enhance sensory qualities of meat. ES has influence on following features as shown in Table 1.

Table 1: *Quality (signs and features) of Meat.*

Facts Utilization	• Tenderness • Flavour • Juiciness • Lipid and Fatty Acid Content

To classify and recognise the internal and external quality signs abundant research has been carried out in relation to meat (Mekeith and Dutson, 1981).

Color

Color is a major sensory attribute that attracts buyer. It gives the feel of freshness. It is considered as an important parameter to check the quality of meat as shown in Table 2. In tenderness, ES also influence coloring of meat; color in pork (Taylor and Martoccia, 1995), lambs (Polidori et al., 1999), beef (McKenna et al., 2003; King et al., 2004), venison (Wiklund et al., 2001), chevon (Savell et al., 1977; Cetin et al., 2012) and chickens (Birkhold and Sams, 1993; Aalhus et al., 1994).

Mechanism

ES works by reducing chemical substances required to carry out oxidation reaction in muscles (Lawrie and Ledward, 2014). Or it may be due to rapid reduction in pH resulting in an instant achievement of isoelectric point of myofibrillar proteins in ES meat that open up proteins structure, hence carrying out oxidation of myoglobin. Hence, due to this ES meat get an instant brighter color than non-stimulated ones after 12 to 20 hours of slaughtering. But there is no clear change in color if exposure is after 48-72 h of slaughtering (Lawrie and Ledward, 2014). It is because both stimulated and non-stimulated meat pH get reduced to this time. Myofibrillar proteins exposed and myoglobin oxidation may be at same stage (Lawrie and Ledward, 2014). Young et al. (1999) studied the influence of ES on 96 chickens, they found improvement in brightness but reduced effect on redness of *Pectoralis major* M. having acidic pH. (Warriss, 2001) reported that shiny appearance of meat could be due to the breakdown of proteins causing the fast decrease in pH resulting in a lighter reflectance on meat surface. Nazli et al. (2010) experimented that ES cows at voltage 500-800 volts, showed a shiner appearance with fast pH reduction than that of non-stimulated beef carcass. Roeber et al. (2000) reported that ES beef showed positive response on color due to decline in meat aging. (Sleper et al., 1983) and (Martin et al., 1983) reported positive impact on color of bovine muscle by ES. On the other hand, (Ledward et al., 1986) reported that ES bovine *Semimembranosus* M. showed dull color due to the generation of metmyoglobin. Hector et al. (1992) reported that at room temperature LVES results in pH reduction (less than 6) in beef causing dull color accompanied with myosin reduction. In sheep HVES results in pale and dull color of *Longissimus thoracis* M. and red, pale color of *Gluteus medius* M. in lambs (King et al., 2004). ES lamb meat showed shiny color rather than non-stimulated ones (Kerth et al., 1999).

Tenderness

To increase the tenderness of meat is the main objective of ES (Aalhus et al., 1994; Simmons et al., 2008; Kemp et al., 2010). To check the palatability of meat it's the most necessary factor as shown in Table 2. ES is applied at wide range to enhance tanderness and other meat sensory attributes (Warriss, 2001). Authors also reported that cold shortening is prevented by ES (Cross, 1979; Bouton et al., 1980; Mota-Rojas et al., 2012). While according to others, it may be due to changes in temperature and pH reduction (Bendall et al., 1976; Dutson et al., 1980). (Savell et al., 1977; Dutson et al., 1980) reported that

Links Researchers

Table 2: *Consumer signs at facts Utilizations: Technical information and interest by industries.*

Facts utilization	Technical information	Interest by industries
Tenderness	Biochemistry of Muscle** Measurements and arrangements* Factors related to before and after slaughtering**	Adopted moderately for best practice**
Flavor	Interaction of flavor* Factors related to before and after slaughtering *	Adopted poorly for best practice*
Juiciness	Chemistry of Meat*** Factors related to before and after slaughtering *	Adopted poorly for best practice**
Lipid and Fatty Acid Content	Factors related to before and after slaughtering **	Adopted poorly for best practice*

*Substantial***, Reasonable**, Restricted*.*

ES causes the leakage of Ca^{2+} from calcium ion reservoir resulting in the protein denaturation by calpain. And cathepsins can also be discharged by lysosomal membrane followed by pH reduction (Dutson et al., 1980; Koohmaraie, 1996). Lawrie and Ledward (2014) reported that ES improve tenderness along with prevention of cold shortening could also be due to protein denaturation at *in vivo* temperatures.

It was reported that in non-stimulated pigs and ruminants meat optimum level of pH is achieved after 10 to 12h of slaughtering while in ES meat it is achieved after 1 to 2h of slaughtering. By applying ES muscle shrinkage occur resulting in higher rate of glycolysis and a fast pH reduction. This pH reduction results rigor mortis that cause muscle to relax (Warriss, 2001). Due to this calcium discharges from cells increasing calpain activity and protein denaturation results in enhanced tenderness (Elgasim et al., 1981; Ducastaing et al., 1985). The tenderness is improved by protein denaturation during meat aging. Ahn et al. (2001) and Ducastaing et al. (1985) reported that this improvement in tenderness may be due to three reasons. One of these is to increase the rate of rigor mortis hence preventing cold shortening. Secondly, ES causes calcium discharge resulting in high calpain activity that denatures myofibrillar proteins. And lastly, ES cause excessive muscular shrinkage that break down myofibril structure. Cross (1979); Honikel et al. (1983) suggested that by applying ES tenderness improved due to inhibition of cold shortening resulting from fast reduction in pH along with faster rate of ATP reduction at high temperature enhancing proteolytic enzyme action hence damaging muscle proteins. ES along with mechanical method and enzymes enhance meat tenderness by decreasing meat aging time and generating a more soft meat with shiny appearance (Yanar and Yetim, 2003). Meat aging/maturation is required to enhance meat quality attributes. ES is used to decrease meat aging time hence improving meat sensory traits. Level of meat tenderness can be determine through level of myofibrililar protein denaturation. Takahashi et al. (1987) reported that ES increases tenderness by physical injury resulting in muscular contractions. ES prevents cold shortening because of non-enzymatic disorderness of myofibrillar proteins (Takahashi, 1992) facilitated by lysosomal enzymes (Dutson et al., 1980). Tenderizing effect of ES can be changed by combination of two or more following procedures.

Juiciness

Different authors reported different type of impacts of ES on meat juiciness. Some of them found positive impact of ES on juiciness (Hwang and Thompson, 2001). Ferguson et al. (2000) revealed negative impact of ES on juiciness. And on the other hand, Jeremiah and (Martin et al., 1983) found no impact. The reason behind the variations in their work that it may depends on impact of ES on meat pH value, disintegration level of muscle fibers and level of protein denaturation as shown in Table 2. And it may also include the impact of back fat and intramuscular fat quantity. Fast pH reduction rate due to ES along with insulation effect of fat causes the reduction in water holding capacity and enhance the muscle denaturation rate. Ferguson et al. (2000) also found the enhanced juiciness in cattle who were given grass than others.

Palatability

ES found to enhance eating quality of meat. Tenderness is the most important characteristic to determine meat quality. In Texas A and M University, various studies have been made to introduce procedures to enhance tenderness. These techniques include: alternate suspension, high temperature, prolonged freezing and cooler aging. Mode of action includes shrinkage of connective tissues or muscles or both. During freezing of carcass, many changes occurs known as rigor mortis. To get desired results, changes can be done in conditions during rigor mortis. According to experiment, tenderness was increased by 23, 9, 24, 29 % in beef, pork, lamb and goat meat. Sensory evaluation showed that steaks were 26, 3, 12, and 32 % more tender than non-stimulated carcasses of beef, pork, lamb and goat respectively.

Meat microbiological quality

Food safety is the main objective of meat industry. Experiments were made to check the impact of ES on microbial load in meat. Reduced amount of bacteria in ES meat as compared to non-stimulated ones. According to authors, by applying ES pH reduction occurs due to accumulation of lactic acid that makes unfavorable environment for microbial functioning. But pH only ceases bacterial functioning but don't destroy them. Ockerman and Szczawinski (1983) revealed that ES reduces pH at the onset of postmortem and aerobic microbes of beef tissues injected with different types of microbes. But microbial load increases when this meat is stored at 0-2 °C in presence of oxygen for 2 weeks. Butler et al. (1981) conducted experiment for pH and microbial load on minced meat taken from bovine *Infraspinatus* and *Biceps femorus* M. The meat was hitherto inoculated with *Pseudomonas* spp, *Moraxella* spp, *Lactobacillus* spp, *Brochothrix thermosphaca*, *Acinetobacter* spp and *Erwinia herbicola*. ES was applied to that meat at 550 V, 16 pulses at the interval of 1.8 s. Both inoculated and non-inoculated meat with or without ES were checked for same microbial load. The authors concluded that there was decline in pH of ES meat but not a clear difference was found.

Ockerman and Szczawinski (1983) studied that ES very minutely decreases heat resistance of Pseudomonas putrefaciens and Lactobacillus plantarum instead of Streptococcus faecalis. Studies were made on ES, hot and cold deboning, bacterial count and beef cuts (Kotula and Emswiler-Rose, 1981). They found that ES and hot and cold deboning has no impact on growth of aerobic bacteria. Ockerman and Szczawinski (1983) also studied the combined effect of ES and processing techniques on meat microbial retention. There was no synergic effect found between meat stored at -21°C and ES implication, between ES and 3% salt and between ES and 3% salt+200 ppm nitrate. But cooking at 60°C and ES had found to have combined effect. They also suggested that reduced pH has no impact on heat-resistance due to ES.

Safety and installation

Food Safety and Inspection Service (FSIS) along with Occupational Safety and Health Administration (OSHA) has made safety and hygienic principles to use ES machines. These safety measures includes: Danger signs should be displayed clearly. There should be special buttons to stop electric current in case of emergency. Main button should be at off position to prevent any untrained person to use it.

Conclusions and Recommendations

By Innumerable studies it has been showed that to enhance different meat quality traits the ES is an effective technique especially for tenderness of meat. However, the success of the technique is premised on several multifaceted factors that cut across antemortem, perimortem and postmortem phases of an animal. The capacity to hasten postmortem glycolysis is the main characteristic of ES. Inception as well as resolution of rigor is accelerated by ES the thus reduces labor and processing time. Electrical stimulation also provides room for other processes to be carried out just immediately after bleeding and cleaning.

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Novelty Statement

ES influences the postmortem glycolysis which leads biological and tissue level changes. ES increases the propagation and termination of rigor mortis hence decreases the processing time and fatigue. The importance of ES is still not that much observed in developing countries,so further research is needed.

Author's Contribution

All authors contributed to write and read the manuscript and agree to be responsible for any aspect of the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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