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Effect of Carcass Electric Stimulation on Meat Quality

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Abstract: The research for post-mortem tenderizing methods comes about from the need to provide good tasting and uniform quality in meat products, considering tenderness as the most important quality characteristic. A number of researchers studied various methods in order to improve meat tenderness cause by the physico-chemical condition of muscle contractile proteins, connective tissue or both. During *post mortem* storage, the muscle undergoes a series of biochemical, histological and physical events which collectively are called *rigor mortis*. Variation of *rigor mortis* events largely influences meat acceptability. Electric Stimulation (ES) directly affects meat sensory characteristics (color, odor and flavor and tenderness). Other factor determining meat quality of stimulated meat are time elapsed from slaughtering to stimulation, ripening and storage temperature after stimulation.

Key words: Carcass, meat tenderizing, electric stimulation

INTRODUCTION

The factors determining quality of raw meat, as well as meat subjected to refrigeration, freezing or any other treatment involve its nutritive value, sanitation, sensory characteristics and its possible use as raw material for further processing. These factors can be grouped in those originated before birth or genetic; occurring during the animal growth or environmental (Mota-Rojas *et al*., 2006; Becerril-Herrera *et al*., 2007) and those resulting from meat handling and processing (Maldonado *et al*., 2007), including meat ripening, storage and specific operations for meat transformation into fabricated products (Guerrero *et al*., 2007). All of these factors determine meat preservation and quality (Stiffler *et al*., 1982).

During *post mortem* storage, the muscle undergoes a series of biochemical, histological and physical events, all together called *rigor mortis*. If one or several of these events are modified, product acceptability may be altered (Stiffler *et al*., 1982). Tenderness, in addition to color and flavor, is considered the most important characteristic of meat (Soria and Corva, 2004; Castañeda *et al*., 2005). Looking for an efficient *post mortem* tenderizing method is a result of consumers' demand for good tasting and uniform quality meat (Stiffler *et al*., 1982). Several researchers developed methods to improve meat tenderness; muscle contractile proteins, connective tissue or both are usually affected by these processes.

Electric Stimulation (ES) is one step in meat transformation; it enhances sensory characteristics (color, odor and flavor and tenderness). Early studies in ES were carried out during the 1940´s in the United States, although without considerable success. Sams (1999) pointed out that ES meat was industrially produced in the 1950´s, aimed for meat processing. During 1970's this method was used to avoid cold shortening in lamb

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carcasses. In 1975 some prototype stimulators were incorporated in American abattoirs; these prototypes were considerably improved during the following decades and at present some ES equipments handle up to 300 animals per hour (Guerrero *et al*., 2004).

ES consists in the application of an electric current to the carcass of recently slaughtered and eviscerated animals. By supplying an electric current, the muscle fibers extensively contract and suddenly undergo extension preventing further contraction or *rigor mortis* and, as a consequence, further muscle shortening. This effect is also known as physical disruption of the myofibrillar matrix or proteolysis acceleration; it increases glycolysis rate and causes an immediate pH drop (Byrne *et al*., 2000; Hwang, 2003).

The effect of ES on meat quality is discussed in this study, reported results are discussed and biochemical and sensory characteristics of stimulated and non-stimulated carcass meat are compared.

PHYSIOLOGY AND BIOCHEMISTRY OF ES MEAT

ES accelerates two of the leading *post mortem* processes: pH decrease to values lower than 6.4 and *rigor mortis* onset, by accelerating glycolysis rate. During ES application the rate of both processes is considerably increased but decreases when electricity application ceases.

ES also prevents thaw-rigor in hot carcass, when meat is frozen before *rigor mortis* resolution. In some cases, ES is applied to excised muscles, although it should be carried out within 30 min after sacrifice, when muscles are still attached to the skeleton (Prändl *et al*., 1994).

ES allows carcass or primal cuts to be refrigerated or frozen just at the end of the slaughter line, without previously allowing onset and resolution of *rigor mortis*. In this way the advantage of using ES is mainly in avoiding carcass shorting during *post mortem* refrigerated storage due to rapid temperature decrease.

From the physiological point of view, the mechanism responsible for ES meat tenderization is by Ca^{++} ion-release from the sarcoplasmatic reticulum; myosin-ATPase is then activated promoting muscle contraction. Calcium liberated during muscular contraction stimulates calpains, specific sarcoplasmic proteases disrupting the Z-line. Due that when this event occurs, muscle temperature is still high (around 30°C) and pH is above 6.5, calpains are highly active. Lysosomes are also probably disrupted releasing cathepsins, another endogenous proteases, which also promote muscle proteolysis (Warris, 2000).

Conversely, during cold shortening-when hot carcasses are refrigerated (at approximately 10-15°C) in *pre rigor* conditions, before dissipation of body heat-calcium ions are massively liberated from the sarcoplasm by disruption of the calcium pump, while myosin-ATPasa is still active; at the same time, muscle ATP concentration is still high providing enough energy for contraction. As a result, the muscle severely contracts producing very tough meat, even more evident when cooked.

Toughening is even more marked when thaw rigor takes place (Lopez and Casp, 2004). This occurs when *pre rigor* meat is frozen (at less than -10°C) (Lawrie, 1991). In this situation ATP has not depleted yet; calcium remains in the sarcoplamic reticulum, even though the calcium pump is disrupted due to freezing. When thawed, massive calcium release occurs, while ATP is still at high concentrations, the result is an extremely severe shortening, even more than in cold shortening. It has been reported that an excised muscle undergoing thaw rigor shortens up to 30% of its original length (Lawrie, 1991). However, muscle length in thaw rigor meat as well as in cold shorten meat, is prevented up to certain point due to muscle attachment to the skeleton.

In addition, thaw rigor can be prevented by several methods, among others by allowing onset and resolution of *rigor mortis* at 14-16°C, by suspending the carcass in altered positions such as pelvic suspension, or by ES (Prändl *et al*., 1994). ES fully depletes ATP to IMP, thus no energy is supplied for protein polymerization, hence for consequently muscle contraction. In this situation, freezing does not affect meat tenderness as no further polymerization can take place (Savell *et al*., 2005).

EFFECT OF ES ON MEAT SENSORY CHARACTERISTICS

Sensory characteristics are possible the main factor determining meat quality. Failure in fulfilling characteristics expected by the consumer will result in economic losses for the producer; they depend on numerous factors, including handling before and after slaughtering. Therefore, ES application also results in improving sensory characteristics.

Channon *et al*. (2003) comments that ES benefits largely depend on the stunning method as well as voltage applied when electric stunning is used; time elapsed after killing also influences optimal conditions for ES.

Davel *et al*. (2003) studied sensory characteristics of meat obtained from stimulated carcasses of 22 castrated Dorper sheep (40-50 kg). Stimulation was at 20 V, 45 Hz for 45 sec, the carcasses were then refrigerated for 24 h at 2°C, *Longissimus thoracis* and *lumborum* muscles were excised and cut into two, vacuum packaged and frozen at -30°C before the sensory evaluation. The right *Longissimus lumborum* was grilled at 160-73°C internal temperature. Results showed higher acceptability of stimulated as compared to non-stimulated samples. ES did not affect cooking losses, associated to weight at sacrifice and carcass fat.

Studies carried out with 12 female alpacas, applying various stimulation voltages (500 and 600 V for 30 and 60 sec) after 1-24 h *post mortem*, reported a significant effect on *Longissimus dorsi* pH between treated and non-treated meat (Guerrero *et al*., 2004).

Young *et al*. (1999) studied color changes in 96 chicken carcasses; half of the animals where ES during stunning. The authors concluded that ES produced significantly brighter meat but less intense redness in the *Pectoralis major* muscle. pH in ES meat rapidly decreased, whereas pH decreased in control samples (non-ES) to the same levels in amount 2 h. The bright color of the stimulated carcasses was probably due to rapid muscle acidification caused by protein denaturation which, in turn, caused higher light reflectance on the meat surface (Warris, 2000).

Voltage intensity and duration also affect meat color. One hundred ES bovine carcasses were studied by Roeber *et al.* (2000), the positive electrode was placed in the *Latissimus dorsi* muscle and the negative in the *Biceps femoris* muscle. Average 100 V voltage was compared against high (300 V) voltage and 11 and 16 cps duration at 60 Hz. Color of stimulated *Longissimus* muscles was brighter, redder and less blue as compared to non-stimulated muscles.

Studies carried out by Channon *et al.* (2003) concluded that the application of 50-200 mA for 30 sec constant current to previously bled swine carcasses the time to reach final pH values to 40 min, as compared to 8 h in non-ES carcasses. However, the authors also reported that ES increased exudation.

It has been demonstrated that ES increases beef palatability (Stiffler *et al*., 1982), improves color and reduces ripening time; it also reduces the presence of dark-cutting beef Warriss (2000) reports that ES affects meat acceptance due to flavor changes. Nonetheless, studies carried out by Guerrero *et al.* (2004), showed flavor improvement in 600 V/30 sec stimulated carcasses. Possible, at this voltage stimulation free aminoacids react with other chemicals, producing flavor-related compounds, such as those resulting from Maillard reactions (Gianelli *et al*., 2003).

ES also affects meat odor. Data obtained by Guerrero *et al.* (2004) indicated that applying 500 V/60 sec, meat odor is significantly reduced. Conversely, studies by Owens and Sams (1997) in 36 ES female turkeys (average weight 7 kg, 10 pulses in the neck region at 570 V, 45 mA, 2 and 1 sec), showed that muscular metabolism is accelerated after 2 h *post mortem*, decreasing pH and preventing excessive sarcomere shortening. However, ES had no effect on the cutting, water loss during cooking, fragmentation index or color values, suggesting that *post mortem* ES provide benefits that justify applying this method in turkey processing.

Therefore, as shown by the results obtained from various authors, several sensory characteristics such as odor, color and flavor, juiciness and mainly, tenderness are improved by the application of ES. However, other factors must be considered in these results such as animal species, genetics, handling and animal age and breed.

EFFECT OF ES ON MEAT TENDERNESS

Tenderness, together with color and juiciness, is one of the most important meat sensory characteristics. ES has been successfully used to improve tenderness and overall quality of meat, accelerating the tenderizing process during storage (Pospiech *et al*., 2003; Soria and Corva, 2004).

Myofibrillar proteins and connective tissues constitute the structure of the meat. Connective tissue protein content varies between 2 and 6% in relation to total proteins. This difference is mainly caused by muscle type, species and age of the animal, as well as the specific activity of a given muscle, although muscle metabolic depends on the animal genotype (Pospiech *et al*., 2003).

Meat reaches pH values around 6.0 at 10-12 h *post mortem*; but this value is reached at 1-2 h *post-mortem* in stimulated meat. ES meat shows intense muscular contractions, resulting in fast rate glycolysis and pH decrease. However, this abrupt decrease also influences the development of early *rigor mortis*, followed by rapid resolution that promoted a fast relaxation rate. At the same time, intracellular calcium is rapidly liberated, as a consequence, calpain activity and proteolysis rate are increased, improving meat tenderness (Warris, 2000; Soria and Corva, 2004).

According to Pospiech *et al.* (2003), protein breakdown during ripening results in increasing meat tenderness. This is due to 3 factors related to muscle fiber behavior. First, due to cold shortening prevention by reducing *rigor mortis* slow phase, but accelerating further contraction. Second, due to calcium liberation by ES myofibrillar proteolysis occurred as a result of calpain activation. Finally, myofibril facture occurs due to extreme contractions caused by the electric current.

Improved tenderness can be obtained by a variety of methods including the use of enzymes, mechanical methods and ES, which early onset of *rigor mortis*, decreasing ripening time and producing brighter and more tender meat that is more acceptable in restaurants, hotels and other hospitality businesses (Yanar *et al*., 2003; Soria and Corva, 2004).

Ripening is usually carried out to improve meat sensory characteristics such as tenderness, flavor and odor; ES application reduces ripening time enhancing quality. Ripening stimulated carcasses results in more tender meat than non-stimulated ripened carcasses. Yanar *et al.* (2003) studied 3-5 year 14 mixed breed Western male ovine (black, white faced) applying ES at 350 V for 45 sec, 15 pulses at 1.5 sec intervals on *Longissimus dorsi* and *Semimembranous* muscles. Tenderness was analyzed by a trained panel, finding that tenderer samples were obtained from ES meat.

Studies carried out by Castañeda *et al.* (2005) on 54 female broilers, 1.5-1.6 kg, electrically stimulated at 450 mA, 450 V, 2 sec by 2 sec, 7 pulses/sec, showed that ES *post-mortem* increases meat tenderness as due to accelerated ATP loss, pH decrease and muscular fiber physical disruption. The authors also reported onset of *rigor mortis* at 30-32°C; slow cooling may also cause pale color and water holding capacity reduction.

Zocchi and Sams (1999) and Castañeda *et al*. (2005), pointed out that high voltage (450 mA, 450 V, 2 sec by 2 sec with 7 pulses) ES followed by rapid cooling (4°C) did not alter protein functionality nor produces PSE meat. However, there is evidence that slow cooling after ES could negatively affect water holding properties of the meat.

Soria and Corva (2004), studied the effect of ES on beef, lamb and chevron. The two groups agreed that ES promotes *post-mortem* glycolysis acceleration, causing the onset of *rigor-mortis* in muscle fibers before cold shortening take place and significantly increasing sarcomere length. The results show that ES had an effect in reducing tenderness suggesting that ES could be applied to meat obtained from old animals to reduce variation in tenderness due to age, breed, species, slaughtering method and nutritional factors.

The effect of sex was studied by Zywica and Katarzyna (2003). These authors studied 18 month heifers and bulls. ES was carried out on the left carcass half at 330 V, 17 Hz, 0.9 pulses for 120 sec. The right half was the control. Twenty four hours after stunning, the hemiaponeurotic muscle was separated from the carcass and divided into 1 kg sections. Sensory and instrumental analysis showed that high voltage ES effect on cooked meat depends on sex of the animal. Better meat quality was obtained from ES heifer hemiaponeurotic muscle.

Marination is a process where meat is subjected to salts affecting the electronic environment of muscle fibers or activating specific enzymes, such as calpains and modifying meat texture (Pérez-Chabela *et al*., 2005). Young *et al*. (2004) studied the effect of ES on 93 poultry breasts marinated with polyphosphates. ES was applied at 220 V alternating current for 90 and 0.5 sec on main effects and testing main effects and interactions for followed by 1 sec off. pH rapidly decreased and sodium tripolyphosphate absorption was increased; water loss after cooking was not affected. The same group (Young *et al*., 2005) analyzed the force required to cut *Pectoralis major* muscle of 52-56 day 40 broilers electrically stimulating the carcass for 90 sec with 220 V, 132-140 mA per carcass, after evisceration the carcass meat was cooled for 3 h with ice. Less force was required in stimulated meat, higher yields were obtained after cooking.

IMPLICATIONS OF ELECTRICAL STIMULATION

ES has been reported as an efficient technique to improve meat quality, especially tenderness y various animal species. However, it involves several complex technological factors to be controlled for being successful. This technique is mainly attributed to glycolysis acceleration, preventing excessive muscular fiber shorting. As onset and resolution of *rigor-mortis* is accelerated in ES carcasses, it allows refrigeration, or even freezing processes, to be applied just after slaughtering and cleaning, processing time is considerably reduced. On the other hand, as the process reducing processing time and labor, it also represents employment loss when applies in developing countries, where more employment is necessary.

REFERENCES

Byrne, C.E., D.J. Troy and D.J. Buckley, 2000. Postmortem changes in muscle electrical properties of bovine M. longissimus dorsi and their relationship to meat quality attributes and pH fall. J. Food Sci., 43 (5): 1392-1396.

Becerril-Herrera, M., D. Mota-Rojas, I. Guerrero-Legarreta, M. González-Lozano, P. Sánchez-Aparicio, C. Lemus-Flores, S. Flores-Peinado, R. Ramírez-Necoechea and M. Alonso-Spilsbury, 2007. Effects of additional space during transport on pre-slaughter traits of pigs. J. Biol. Sci., 7 (7): 1112-1120.

Castañeda, M.P., E.M. Hirschler and A.R. Sams, 2005. Research note functionality of electrically stimulated broiler breast meat. Poul. Sci., 84: 479-481.

Channon, H.A., S.R. Baud and M.G. Kerr, 2003. Effect of low voltage electrical stimulation of pig carcasses and ageing on sensory attributes of fresh pork. Meat Sci., 65: 1315-1324.

Channon, H.A., T.J. Walker, M.G. Kerr and S.R. Baud, 2003. Application of constant current, low voltage electrical stimulation system to pig carcasses and its effects on pork quality. Meat Sci., 65: 1309-1313.

Davel, M., M.J. Bosman and E.C. Webb, 2003. Effect of electrical stimulation of carcasses from Droper sheep with two permanent incisors on the consumer acceptance of mutton. South Afr. J. Anim. Sci., 33 (3): 206-212.

Gianelli, P., M. Flores and F. Toldrá, 2003. Interactions of soluble peptides and proteins from skeletal muscle on the release of volatile compounds. J. Agric. Food Chem., 51: 6828-6833.

Guerrero, M.Y., S. Flores-Peinado, M. Becerril-Herrera, A. Cardona-Lejia, M. Alonso-Spilsbury, M. Zamora-Fonseca, J. Toca, R. Ramírez-Necoechea, J.A. Toca and D. Mota-Rojas, 2007. Insensibilization of California breed rabbits and it's effect on sanguineous pH, temperature, glucose levels, creatine kinase and slaughter performance. J. Anim. Vet. Adv., 6 (3): 410-415.

Guerrero, M.O., L.M. Vilca, D.C. Ramos, C. Lucho and P.N. Fálcon, 2004. Estimulación eléctrica de canales de alpacas para mejorar su calidad organoléptica. Revista de. Investigación Veterinaria Perú, 15 (2): 151-156.

Hwang, I.H., C.E. Devine and D.L. Hopkins, 2003. The biochemical and physical affects of electrical stimulation on beef and sheep meat tenderness. Meat Sci., 65: 677-691.

Lawrie, R., 1991. Avances de la Ciencia de la Carne. Zaragoza: Acribia, pp: 222-223.

López, V. and V.A. Casp, 2004. Colección Tecnología de Alimentos. Tecnología de Mataderos. España: Ediciones Mundi Prensa, pp: 177-179.

Maldonado, M.J., D. Mota-Rojas, M. Becerril-Herrera, S. Flores-Peinado, D. Camacho-Morfín, A. Cardona-Leija, R. Ramírez-Necoechea, L. Morfín-Loyden, M. González-Lozano, M.E. Pereda-Solís and M. Alonso-Spilsbury, 2007. Broiler welfare evaluation through two stunning methods: Effects on critical blood variables and carcass yield. J. Anim. Vet. Adv., 6 (12): 1469-1473.

Mota-Rojas, D., M. Becerril-Herrera, C. Lemus, P. Sánchez, M. González, A. Olmos, R. Ramírez and M. Alonso-Spilsbury, 2006. Effects of mid-summer transport duration on pre- and post-slaughter performance and pork quality in Mexico. Meat Sci., 73 (3): 404-412.

Owens, C.M. and A.R. Sams, 1997. Muscle metabolism and meat quality of pectoralis from turkeys treated with postmortem electrical stimulation. Poul. Sci., 76: 1047-1051.

Pérez-Chabela, M.L., I. Guerrero-Legarreta, M.C. Gutiérrez and M. Betancourt, 2005. Effect of calcium chloride marination and collagen content on beef, horse, rabbit and hen meat hardness. J. Muscle Foods, 16 (2): 141-154.

Pospiech, E., B. Grzés, A. Lyczynski, K. Borzuta, M. Szalata and Mikolajczak, 2003. Muscles proteins and their changes in the process of meat tenderization. Anim. Sci. Rep., 21: 133-151.

Prândl, O., A. Fisher, T. Schmidhofer and H.J. Sinell, 1994. Tecnología e Higiene de la Carne. Ed Acribia, pp: 124-126.

Roeber, D.L., R.C. Cannell, K.E. Belk, J.D. Tatum and G.C. Smith, 2000. Effects of a unique application of electrical stimulation on tenderness, color and quality attributes of the beef longissimus muscle. J. Anim. Sci., 78: 1504-1509.

Sams, A., 1999. Commercial implementation of postmortem electrical stimulation. Poul. Sci., 78: 290-294.

Savell, J.W., S.L. Mueller and B.E. Baird, 2005. The chilling of carcasses. Meat Sci., 70: 449-459.

Soria, L.A. and P.M. Corva, 2004. Factores genéticos y ambientales que determinan la terneza de la carne bovina. Arch. Latinoamericanos Prod. Anim., 12 (2): 73-88.

Stiffler, D.M., J.W. Savell, G.C. Smith, T.R. Dutson and Z.L. Carpenter, 1982. Electrical stimulation: Purpose, application and results. Bull. B-1375, Texas Agric. Ext. Serv. College Station, TX.

Warriss, P.D., 2000. An Introductory Text. Meat Science. CABI Publishing. New York. Chapter, 8: 162-167.

Yanar, M. and H. Yetim, 2003. The effects of electrical stimulation on the sensory and textural quality properties of mutton carcasses. Turk. J. Anim., 27: 433-438.

Young, L.L., R.J. Buhr and C.E. Lyon, 1999. Effect of polyphosphate treatment and electrical stimulation on postchill changes in quality of broiler breast meat. Poult. Sci., 78: 267-271.

Young, L.L., D.P. Smith, J.A. Cason, J.M. Walkers and B. Richard, 2004. Effects of Intact Carcass electrical stimulation on moisture retention characteristics of polyphosphate treated non-aged boneless broiler breast fillets. Int. J. Poult. Sci., 3 (12): 796-798.

Young, L.L., J.A. Cason, D.P. Smith, C.E. Lyon, A. Dickens and J.M. Walker, 2005. Effects of electrical stimulation and simulated conventional- and extended chilling method on cooked chicken breast meat texture and yield. Int. J. Poult. Sci., 4 (2): 60-63.

Zocchi, C. and A.R. Sams, 1999. Tenderness of broiler breast fillets from carcasses treated with electrical stimulation and extended chilling times. Poult. Sci., 78: 495-498.

Zywica, R. and B.J. Katarzyna, 2003. The influence of high-voltage electrical stimulation and animals′ sex on the selected attributes of quality of cooked beef hams produced from semitendinosus muscle. Food Sci. Technol., 6 (2): 1-6.