EFFECT OF LOW VOLTAGE ELECTRICAL STIMULATION AND STORAGE CONDITIONS ON THE FUNTIONAL CHARACTERISTICS OF BEEF USED IN EMULSION TYPE PRODUCTS

Efecto de la estimulación eléctrica a bajo voltaje y del almacenamiento en las propiedades funcionales de las carnes utilizadas en la elaboración de productos cárnicos emulsificados

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Key words: Stimulation, low voltage, funtional properties, beef

Palabras claves: Estimulación, bajo voltaje, propiedades funcionales, carne de bovino

ABSTRACT

Ten standard grade steers were used to determine the effect of low voltage electrical stimulation and storage treatments on water holding capacity (WHC), emulsifying capacity (EC) and emulsion stability (ES) of beef used for emulsion type products.

Five animals were slaughtered and the carcasses immediately stimulated and five were not stimulated and served as control. Fresh (3 d, 0°C) and frozen (60 d, — 16°C) beef trimmings from stimulated and nonstimulated carcasses were used to determine WHC, EC and ES of the meat protein.

Low voltage stimulation effectivety lowered the pH values of the stimulated sides when compared to control sides, and a low pH (5.9) high temperature (35°C) conditions were created. However, the ultimate pH value was not affected. Emulsifying capacites water holding capacities and emulsion stability were not affected by stimulation treatments, but by storage condition. Fresh meat gave higher emulsion stability.

RESUMEN

Diez novillos fueron utilizados para determinar el efecto que la estimulación eléctrica a bajo voltaje (75V) y la temperatura de almacenamiento tienen sobre las propiedades funcionales de las proteínas de las carnes, tales como capacidad de retención de agua, capacidad de emulsificar grasa y de estabilizar emulsiones cárnicas. Cinco animales fueron sacrificados e inmediatamente estimulados. Los otros cinco no se estimularon sirviendo de control. Tanto las carnes estimuladas como las no estimuladas se dividieron en dos porciones, una se almacenó a temperatura de refrigeración (0°C) durante 3 días, y la otra se congeló (— 16°C) durante 60 días. Los resultados indicaron que la estimulación eléctrica a bajo voltaje es efectiva para bajar el pH de las carnes durante las primeras horas postmortem, pero no afecta el pH final. A pesar de que se creó una situación de bajo pH (5.9) y relativamente alta temperatura (35°C) esto no afectó las propiedades funcionales de las proteínas de las carnes. Se observó que la temperatura de almacenamiento afecta estas propiedades. Las proteínas de las carnes refrigeradas mostraron mayor capacidad de emulsificación cuando se compararon con las carnes congeladas.

INTRODUCTION

The stability of meat emulsion depends on factors such as meat proteins[10], type and amount of fat[12] and the processing technology[21]. Two important properties of the meat protein which are highly related with the stability of the emulsion are water holding capacity and emulsifying capacity. Since the majority of the water in meat is present within the myofibril in the spaces between the thick and thin filaments, it therefore seems very likely that changes in the water holding capacity of meat are caused by changes in the interfilament spacing. Factors such as muscle pH, salt concentration and storage condition have been indentified as responsible for causing changes in the interfilament spacing[9, 14, 16].

Presently, electrical stimulation is widely used in the beef industry to increase tenderness. Electrical stimulation of a carcass immediately after slaughter stimulates the muscle to contract and accelerates the postmortem glycolysis rate, exhausting the energy source and resulting in rapid pH decline[2, 3, 6, 18]. The rapid drop in muscle pH while muscle temperature remains near body temperature is believed to have a detrimental effect on the ability of the protein to stabilize a meat emulsion.

High voltage electrical stimulation involves direct depolarization of muscle membranes and can be applied

later during the slaughter time when a decrease in temperature has occurred. However, low voltage electrical stimulation requieres a functional nerve system and has to be applied immediately after slaughter while the muscle temperature is near the body temperature The low pH-high temperature condition created by low voltage stimulation may have a detrimental effect on functional properties of the muscle.

All studies on low voltage electrical stimulation to date have been on the properties of intact muscle (steaks and roasts). However, trimmings and some skeletal meats from carcasses stimulated to accelerate chilling and boning will also be used in the manufacture of meat products.

This study was undertaken to determine the effect of low voltage electrical stimulation and storage condition on the functional and processing properties of meat used in the manufacture of emulsion type products.

MATERIALS AND METHODS

Ten U.S.D.A. standard grade steer carcasses were used. Five carcasses were randomly selected and electrically stimulated with low voltage (75V) for 36 sec immediately after stunning, suspension and initiation of exsanguination, using a Koch-Britton Stimulator 75-LW. 14 hertz frequency, square wave, alternating polarity. The other five carcasses served as nonstimulated controls.

pH and temperature

The pH values of the triceps brachii muscle were determined by inserting a combination pH probe into the muscle at, 1, 2, 3, 4, 5, 6, 8, 10, 12 and 24 hr postmortem. The pH was monitored using a Radiometer/Copehagen PHM 63 digital pH meter.

The internal temperatures of the triceps brachii muscle during the chilling period were measured by placing copper constantine thermocouples into the deepest region of the triceps brachii muscle. Temperatures were recorded on a Leeds and Northrup Sppedomax Recorder (Model n°w) for the first 24 hr postmortem.

Funtional parameters

Chucks and plates from each carcass were removed and boned at 72 hr postmortem.

Waterholding capacity of the lean sources expressed as expressible moisture loss was determined by the press method outlined by Terrel et al[21].

Emulsifying capacity of the lean beef sources was determined using the procedure developed by Marshall et al[11]

Emulsion Stability was performed by the test developed by Townsend et al[22].

Statistical analysis

The design consisted of the utilization of a split-plot with the main plot being stimulation treatments and the subplots being storage (fresh or frozen) treatments. Data collected from this study were analyzed using the Statistical Analysis System (SAS) PROC GLM[17] and the mean separation technique of Duncan[5].

RESULTS AND DISCUSSION

pH time and pH/temperature curve

The effects of low voltage electrical stimulation (ES) on pH decline in the triceps brachii muscle are shown in Fig. 1. It was evident that postmortem electrical stimulation employed was successful in accelerating the rate of pH fall during the early postmortem times. Two distinct phases of glycolysis can be distinguished as a result of the low voltage ES, Fig. 1. The first phase lasted about 2 hr during which a very pronounced drop in pH of about 1 unit occurred, the majority of which occurred during stimulation. The second phase started 2 hr postmortem during which the rate of pH fall was slower than the first phase and was comparable for both stimulated ad nonstimulated sides.

The average pH of the stimulated sides had dropped to below 6 after 2 hr postmortem, while the pH values for the control sides averaged 6.4 and took about 7 hours to reach pH 6, Fig. 1. However, the final ultimate pH was comparable for both stimulated and nonstimulated sides at 24 hr postmortem. This indicates that although ES accelerates the drop in pH, it does not bring it below the normal ultimate pH of meat.

The pH/temperature curves for the ES and control sides are given in Fig. 2. Apart from the well known acceleration effect of ES on rate or pH fall, the most significant feature is the quite different temperature histories of the control and stimulated sides in relation to pH. The averaged pH of stimulates sides had declined to below 6 while the muscle temperature was still higher than 35°C. However, the control sides were 27°C when pH reached a value less than 6. This low pH-high temperature condition created in the stimulated sides has been reported to produce a detrimental effect on the functional properties of the meat proteins[7, 20].

Water holding capacity (WHC) values are shorun in Table I. Although low voltage ES created a low pH (5.9)-high temperature (>35°C) condition, this combination was not drastic enough to produce changes ($P>0.05$) in the WHC of the meat proteins. This result agree with those observed by Savel et al[19] usin nigh voltage ES but disagree with those observed by Bouton et al[2]. However, Bouton et al[2] used cooking loss to express WHC and this technic requires a more severe treatment than the one used in this study.

Significant differences ($P>0.05$) due to storage treatments were observed Table I suggesting that fresh lean meat had higher WHC than frozen meat.

It has been stated that the reduction in WHC during freezing is due to some destruction of protein structure by

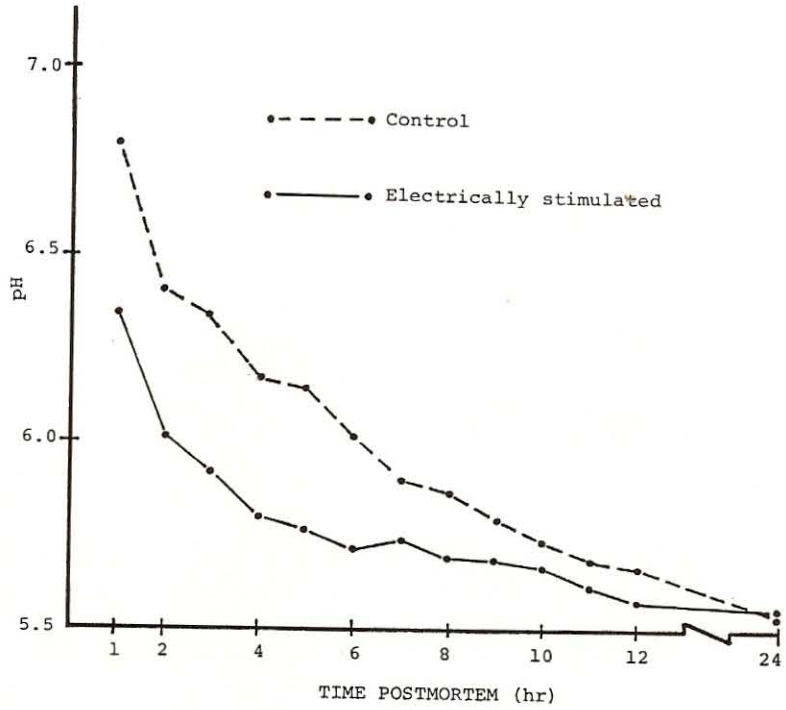

FIG. 1. Postmortem pH decline in the triceps brachii muscle.

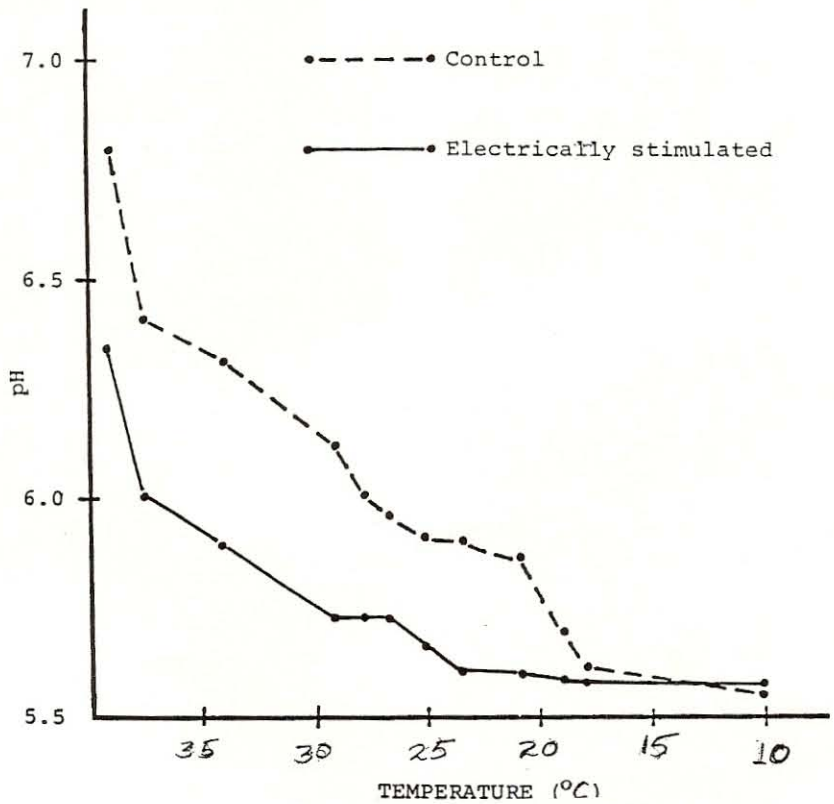

FIG. 2. Temperature histories of the triceps brachii muscle in relation to pH during postmortem chilling.

TABLE I

MEAN VALUES FOR BINDING CHARACTERISTICS OF LEAN BY STIMULATION AND STORAGE TREATMENTS

	Treatments			
	Stimulation[a]		Storage	
Characteristics	**ES**	**C**	**Fresh**	**Frozen**
Water holding capacity[b]				
Expressible moisture loss, %	27.82[x]	27.73[x]	26.77[x]	28.78[y]
Emulsifying capacity				
ml oil/mg protein	0.24[x]	0.25[x]	0.26[x]	0.23[x]
ml oil/g fresh tissue	26.76[x]	25.65[x]	28.50[x]	23.91[y]

[a] Stimulation was as follow: ES = 75V, ac, immediately after slaughter; C = Control.
[x, y] Means on a row within a treatment group bearing different superscripts differ significantly ($P < 0.05$).

TABLE II

MEAN VALUES FOR EMULSION STABILITY BY STIMULATION AND STORAGE TREATMENTS[a]

	Treatments [a]			
	Stimulation		Storage	
Characteristics	**ES**	**C**	**Fresh**	**Frozen**
Emulsion stability				
Fat, ml	0.82	0.94	0.98	0.78
water, ml	1.91	1.49	1.64	1.77

[a] Means for each treatment comparison were not different ($P < 0.05$).

formation of large ice crystals between the cells[4]. During the initial formation of ice crystals, especially in extracellular spaces, a very high concentration of salt develops in the cells which may cause extensive denaturation of muscle protein[10, 14]. Since it is known that the integrity of the sarcoplasmic reticulum is temperature dependent, it may be possible that high concentration of Ca^{+2} were released during freezing into the myofibrillar spaces producing crosslinkages between proteins molecules, particularly aggregation of the actomyosin. These aggregation squeeze water out of the myofibrillar spaces. This loss in water-binding ability of the proteins, along with cellular damage arising from mechanical disruption of muscle cells by ice crystals formation may be responsible in large part for the increase in the expressible moisture loss.

No differences ($P > 0.05$) were observed in emulsifying capacity due to stimulation treatments. Amount of oil emulsified was similar between treatments when expressed both on a protein or on a fresh basis. It has been claimed that electrical stimulation caused sarcoplasmic proteins to denature onto the fibrils to produce the irregular bands observed under the microscope[8]. These bands have also been interpreted as supercontracted sarcomeres[20, 25]. Others have reported no changes in the solubility of the muscle protein due to electrical stimulation[23]. The absence of detectable major change in emulsifying capacity implied that stimulation did not cause an irreversible reduction of myofibrillar protein ability to emulsify fat.

No differences ($P > 0.05$) were observed in emulsifying capacity due to storage treatments when the emulsifying capacity was expressed as ml oil/mg of protein. However, when the emulsifying capacity was expressed as ml oil/g fresh tissue, frozen meat emulsified less oil than did fresh meat. These findings indicate that the difference in emulsifying capacities of fresh and frozen meat may be due to a reduction in the solubility and decrease protein extraction in frozen meat rather than a reduction of the emulsification capacity. Higher amounts of added water were required for emulsion type products when made from frozen meat in order to keep the same stability as those made from fresh meat[15]. They suggested a possible alteration in the charge of the meat proteins due to the freezing effect that may produce interaction among these proteins and, thus, decreased their emulsifying properties. It has been reported that total extractable protein (sarcoplasmic and actomyosin) decreased with frozen storage with subsequent decreases in emulsifying properties[1]. Miller et al[14] showed reductions in emulsifying capacity due to frozen as compared to fresh meat

samples. They explained this decrease in emulsifying capacity as a consequence of a decrease in the solubility of muscle proteins.

Mean values for emulsion stability by stimulation and storage levels are shown in Table II. Emulsion stability was expressed as ml of fat and water released upon heating per 34 g of emulsion. No differences ($p>0.05$) were observed in emulsion stability due to stimulation treatment. It has been indicated that product pH is very important to emulsifying properties[13, 24]. However, as it was shown in Fig. 1, the low voltage electrical stimulation did not change the final ultimate pH of the meat. Since electrical stimulation did not affect water holding capacity and emulsifying capacity, Table II, then it is reasonable to expect no effect on emulsion stabilitv due to the high relationship among water holding capacity, emulsifying capacity and emulsion stability.

Small, but nonsignificant, differences due to storage treatments were observed, suggesting that fresh meat contribute to the formation of emulsion whit higner stability when compared with the emulsion prepared with frozen meat. This was shown by the higher amount of fat (0.98 vs 0.78) and water (1.77 vs 1.64) released from the emulsion prepared whit frozen meat. However, these differences were not significant ($P>0.05$).

CONCLUSIONS

Data indicated that low voltage electrical stimulation did increase pH decline creating a condition of low pH and relatively high temperature; but had no detrimental effects on the functional and processing characteristics of meat used in the manufacture of emulsion type products. On the ozyer hands, frozen storage adversely affected water holding capacity, and emulsifying capacity but not emulsion estability.

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