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STUDY OF THE EFFECTS OF THE APPLICATION OF ALTERNATING ELECTROMAGNETIC (60 HZ) AND CONTINUOUS ELECTRIC FIELDS IN FOOD: EFFECTS ON MEAT TENDERNESS

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Abstract: Brazil has a prominent role in meat production but must improve its quality, especially concerning tenderness. Tenderness is among the most prominent factors that give meat quality characteristics and is considered the organoleptic characteristic with the most significant influence on consumer acceptance. Thus, this research aimed to improve this characteristic of eye round steak using electromagnetic and electric fields. Some samples were subjected to an alternating electromagnetic field of 34 millitesla at a frequency of 60 hertz obtained through an electromagnet, and others were simultaneously subjected to an alternating electromagnetic field and a uniform electric field of the magnitude of the 400volt.meter^{-1}, originated by two parallel and electrified copper plates. The tenderness of the samples exposed to the fields was compared with each other and the Control. The samples exposed only to the alternating electromagnetic field showed greater tenderness than those exposed to alternating electromagnetic field and a uniform electric field and the control In conclusion, the exposure of eye round samples to alternating electromagnetic field tenderizes the meat. Therefore, this technique is promising in improving the tenderness of this cut without using industrialized tenderizers.
Keywords: Eye round, tenderizing, texturometer, chemical products.

INTRODUCTION

The Brazilian cattle herd reached 214.7 million animals in 2019, a 0.4% increase compared to 2018, the first breakthrough after two years of drops. The data are from the Municipal Livestock Production 2019 of the Brazilian Institute of Geography and Statistics (IBGE in Portuguese). According to information from the United States Department of Agriculture (USDA), Brazil had the second-largest cattle herd in the world in 2018, being the main exporter and the second-largest producer. According to Secex data, 1.5 million tons of beef were exported, increasing 17% compared to 2018, IBGE reports.

Despite these favorable indices, it can be said that national cattle breeding is one of the segments of the meat production sector that has faced difficulties organizing itself and overcoming obstacles inherent in its maintenance and/or market expansion. The opportunities for expanding the beef market are closely associated with the competitive capacity of the productive sector. Consequently, quality is a crucial point. Tenderness is prominent among the various factors that give beef quality characteristics. It is considered the organoleptic characteristic of most significant influence for consumer acceptance (Paz & Luchiari Filho, 2000).

Recent data indicate that, in February 2021, Brazil's beef export doped when compared to the same period of 2020. In February 2021, export revenue accounted for the equivalent of US$ 466.0 million, a decrease of 4.9% compared to January 2020 (US$ 490.0 million). However, it is worth noting that the value of 2020 was a historical record, and, despite the drop, the value of 2021 follows as the second-largest within the historical series. https://www.farmnews.com.br/mercado/exportacao-de-carne-bovina-31/).

This market fluctuation can be attributed to numerous factors, such as the high price of Brazilian beef in American currency or even a factor with quality bias, such as tenderness.

A solution would be turning a low acceptance product into a good palatability commodity without meat tenderizers. Currently, meat can be tenderized using industrialized tenderizers based on proteolytic enzymes of plant origin, such as papain (papaya) and bromelain (pineapple), found in commerce and with effective tenderizing action (Oliveira et al., 2013). However, according to the American Latex Allergy Association, the use of tenderizers of plant origin can cause an allergic reaction to people who have some intolerance to these fruits and may suffer from throat swelling and pain, skin itching, difficulty breathing, and other reactions after eating meat treated with such enzymes. Additionally, most tenderizers contain monosodium glutamate. In large quantities, sodium can affect heart health.

Given this scenario, this research aimed to study the influence of alternating electromagnetic field (EMF) and alternating electromagnetic field and a uniform electric field (EMEF) on meat tenderizing without the use of industrialized products.

MATERIAL AND METHODS

The experimental procedures were carried out at the Center for the Development of Applied Instrumentation in Agriculture (CEDIA in Portuguese) of the Department of Automation (DAT) and the Department of Food Sciences (DCA) of the Universidade Federal de Lavras (UFLA). The manufacture of the electromagnet and the mode of action of the EMF and EMEF are be detailed in items 2.1 to 2.4.

ELECTROMAGNET DESIGN

The electromagnet was built using two cylindrical billets of approximately 0.076 m in diameter (coils) of ferromagnetic material, on which 2000 coils[1] of copper enameled wire number 19 will be wound. These coils constitute the core of the electromagnet. The nuclei will be interconnected by the same ferromagnetic material so that the decrease in the electromagnetic field can be mitigated by scattering induction lines through the surrounding space. The electromagnet was supplied by the conventional alternating electrical network in 120 V, 60 hz. The intensity of the electric current was monitored by an ammeter (A). Figure 1.

EMF MEASUREMENT

The electromagnetic field was measured in the electromagnet air gap region where the meat sample was positioned. This measurement was performed by a Gaussmeter (MGM20, Teknikao, São Paulo, Brazil), which provides electromagnetic field values in Tesla.

PACKAGING OF THE MEAT SAMPLES SUBMITTED TO EMEF

The meat samples occupied a volume of 0.03×0.03×0.04 m between two copper plates of dimensions 0.03×0.04 m and were positioned in the air gap of the electromagnet. Figure 2.

This sample shall be submitted, at the same time, to the EMF temporally variable and to the EMEF (The electric field will be fed by a continuous voltage of 12 V, resulting in a field of uniform characteristics (module, orientation, and direction) and 400 V. m^{-1}.

POSITIONING OF MEAT FIBERS IN RELATION TO EMF/EMEF AND METHODOLOGY FOR POST-MAGNETIZATION SAMPLE ANALYSIS

The meat fibers were perpendicular to the magnetic field vector and parallel to the electric field (Figure 3).

The EMEF was on for 300 s for each sample. During this time, the electric field was alternately on for 50 s and off for 10 s until reaching 300 s. Table 1.

1. This value was reached by knowing the maximum value of the desired magnetic field (B), the value of the coil radius (R), the maximum value of the electric current (i), and by applying the mathematical expression: $B= (\mu_0.N.i)/2\pi R$. $\mu_0= 4\pi . 10^{-7}$ T m A^{-1}. B= (μ0.N.i)/2nR. μ0= 4π . 10-7 T m A-1.

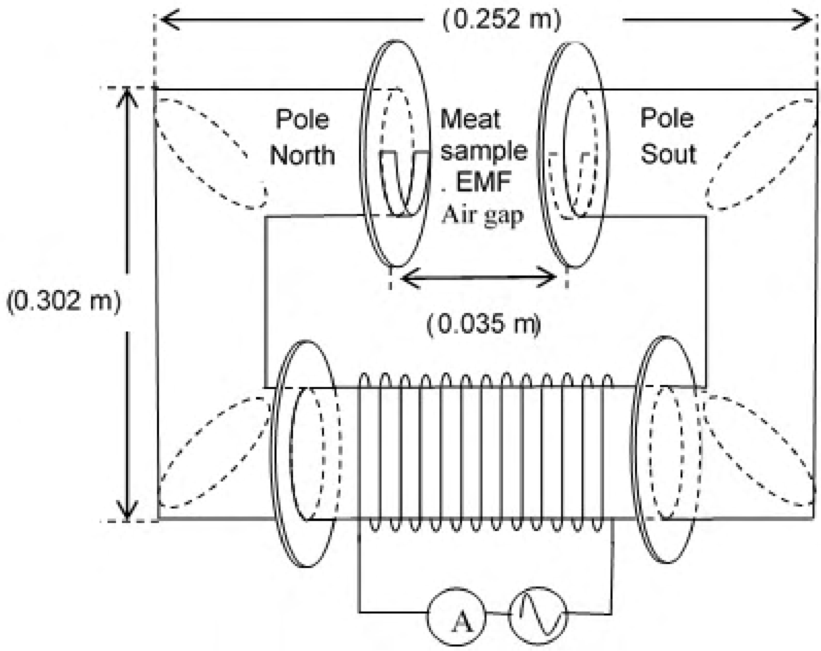

Fig.1. Electrical scheme of the electromagnet. Samples subject to EMF.

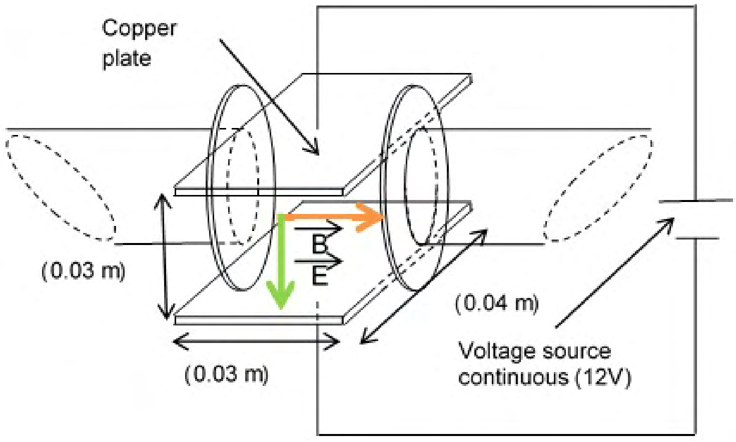

Fig 2. Directions of magnetic and electric field actuation. Samples submitted to EMEF.

Caption: Horizontal vector: magnetic field; vertical vector: electric field.

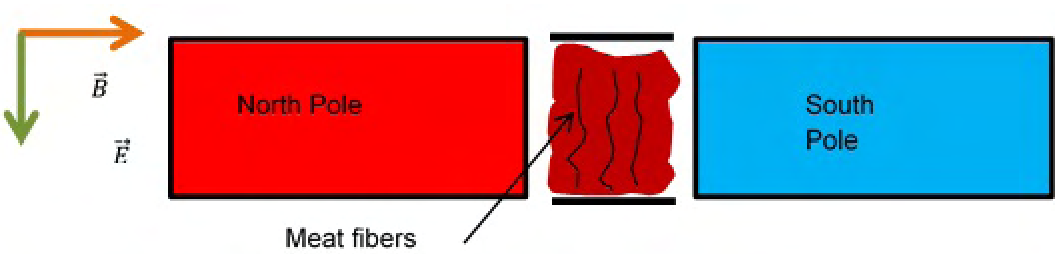

Fig.: 3. Positioning of meat fibers relative to the electromagnetic and electric fields

Time interval in seconds				
	Alternating Electromagnetic Field (0.034 T)	Uniform Electric Field (400 V.m^{-1})		Number of replicates
		On (s)	Off (s)	
Sample 1	300	3000	600	6
Sample 2	300	3000	600	6
Sample 3	300	3000	600	6

Table 1. Methodology for the exposure of samples to the fields and replications

After exposure to the fields, the meat samples were cooked for 420 s, being immersed in boiling water (100 °C) throughout the cooking process.

At the end of cooking, the samples were submitted to the softness test using a model texturometer *TA.XTplus* (Stable Micro Systems Ltda., *Godalming*, *Surrey*, UK).

SAMPLING

The parts of the semitendinous or *semitendinosus* (bovine eye round muscle) were acquired at a slaughterhouse of Lavras, MG.

Each piece was manually cut crosswise into 0.04 m steaks. Then, two pieces/samples in the shape of a parallelepiped were taken from each steak (0.04 x 0.03 x 0.04 m). Each sample was placed inside a plastic bag. The bags were randomly labeled concerning the respective treatment.

Subsequently, the samples were placed in the respective treatment (EMF; EMEF).

SHEAR FORCE (SF)

The sheer force (SF) was determined using the *Warner-Bratzler Square Shear Force method* (WbsSF) described by (Silva et al., 2015). After being submitted to the respective treatment, the eye round sample inside the plastic underwent cooking (100 °C) until the central part of the sample reaches 71 °C. After natural cooling of the sample, the plastic bag was removed, and cuts of 0.01x0.01x0.04 m were made in the direction of the muscle fibers, obtaining duplicates of each sample to perform the shear force analysis. Shear force analysis was conducted using transversal cuts in the direction of the fiber, in the central part of the sample, by a *Warner-Bratzler* blade coupled to a texturometer *TA.XTplus* (Stable Micro Systems Ltda., *Godalming*, *Surrey*, UK), at a speed of 0.00333 m. s^{-1}, The shear force (N) of each sample was determined as the average of the maximum forces recorded in the shear of the duplicates.

STATISTICAL DESIGN

The experimental design used in this work was completely randomized. Three treatments of exposure to EMF and EMEF were compared, using six replicates. The data were submitted to the analysis of variance (ANOVA) using the statistical software SISVAR® (Ferreira, 2014) at 5% probability, by the F test, comparing the means using the Scott-Knott test with 5% significance.

The experimental procedures were carried out at the Center for the Development of Applied Instrumentation in Agriculture (CEDIA in Portuguese) of the Department of Automation (DAT) and the Department of Food Sciences (DCA) of the Universidade Federal de Lavras (UFLA).

RESULTS AND DISCUSSION

The texture of the meat samples treated with EMF and those exposed, concomitantly, to EMEF improved when compared with the Control. There was a considerable difference in the tenderness of the samples submitted to the electromagnetic treatment. There was no statistical difference between the samples that were submitted to the fields (Table 2).

The use of electromagnetic fields applied for this purpose is still very incipient or almost non-existent. However, there have been promising results obtained by some works carried out so far.

A positive influence within intensity patterns and time of exposure of electromagnetic fields in some plant processes, such as potentiation of germination in some seeds, is a consensus in the scientific community (Azevedo, 2018). In this work, *Coffea Arabica* seeds were submitted to electromagnetic fields to speed their germination. The result was brevity of 15 days in the time of root protrusion.

Belyavskaya (2001) concluded that Ca^{+2} ions were the potentially sensitive component of the weak electromagnetic field effect, assuming that the calcium ions connected to the Ca^{+2} binding sites of the proteins were responsible for the processes triggered, confirming the theory of "ion parametric resonance" in magnetobiological effects (Binhi, 2001).

Ca^{+2} ions act directly on phytohormones. In the case of cytokinins, the ion potentiates its action in the expansion of cotyledons and slows senescence (aging process of living beings) and leaf abscission (leaf fall by adaptation to a certain season of the year) by inhibiting the production of ethylene (Hepler, 2005).

The relationship between calcium and meat tenderness is closely related to the calpain enzyme system, formed by two calpains (proteinase activated by a micromolar concentration of calcium or μ-calpain or calpain type I and proteinase activated by a millimolar concentration of calcium or m-calpain or calpain type II), activated by free calcium (not retained in the sarcoplasmic reticulum or mitochondria), and inhibited by another enzyme called calpastatin (koohmaraie, 1994).

Dransfield (1993) proposed a meat tenderizing model based on the activation of calpains by increasing the concentration of free calcium from the beginning of *rigor mortis* - a pH decline from 6.5 to 5.7 increases calpain I activity from 15% to 97% of the maximum activity. The model also includes the inhibition of calpains by calpastatin and the inactivation of calpain and calpastatins by autolysis, to the extent that meat tenderizing occurs.

Some of the evidence from (Goll et al., 1992) that calpains are the main responsible for *post-mortem* tenderizing were transcribed and related by (Taylor et al., 1995):

Treatments	Means (N)
Control	54.7 a_1
EMF	48.6 a_1
EMEF	50.1 a_2

Mean values with the same letter do not differ from each other. Values obtained by the Scott-Knott test at 5%. Coefficient of variation (CV) of 21.15%.

Table 2. Mean shear force values.

1. Increased calcium concentration in the muscle results in increased tenderness. It is known that neither cathepsins nor multi-catalytic proteases are activated by calcium;

2. Greater tenderizing for a large maturation period occurs in muscles that contain large amounts of calpains (mainly, μ-calpain) or low calpastatin activity. Low calpastatin activity is directly associated with increased *post-mortem* tenderness.

Given this evidence, it is argued that the influence of magnetism on the improvement of the tenderness of meats with a worse texture is possibly due to the activation of free calcium ions since they are more susceptible to magnetic force due to having a higher amount of electric charge (3.2×10^{-19} C).

CONCLUSION

The exposure of the eye round samples to the magnetic field tenderized this cut, possibly by activating free calcium ions.

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