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Research Article
Effect of Post-mortem Electrical Stimulation on Meat Quality of Pesisir Cattle (Indigenous Cattle of West Sumatera)

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Abstract

Background and Objective: The quality of meat depends on several factors, such as the treatment given to cattle before they are slaughtered, the slaughter process and carcass treatment after slaughter. Many attempts have been made to maintain meat quality, including electrical stimulation, aging and freezing. Electrical stimulation is a simple technology but it provides a more significant effect on the economic value of the meat. This study aimed to observe the effect of voltage and duration of electrical stimulation on tenderness, protein content and fat content. **Methodology:** A randomized block design with a 2x3 factorial arrangement was used. The first factor consisted of the voltage of electrical stimulation, which was A1 = 110 volts and A2 = 220 volts. The second factor consisted of the duration of electrical stimulation, which included 3 time periods, b1 = One min, b2 = Two min and b3 = Three min and the block consisted of the day when the samples were taken. The variables that were measured include pH, tenderness, protein and fat content of the Pesisir cattle beef. **Results:** This study showed that there is no interaction between the voltage and the duration of electrical stimulation on tenderness, protein content and pH of the Pesisir cattle. Electrical stimulation voltage significantly influenced tenderness and protein content of the Pesisir beef. The duration of electrical stimulation affects the tenderness of the meat, i.e., the longer the stimulation, the higher the tenderness. Average pH of meat obtained in this study was between 5.56-5.63. **Conclusion:** The voltage of electrical stimulation influenced the tenderness, protein and fat content of Pesisir cattle meats. The duration of electrical stimulation significantly increased tenderness but did not affect pH, protein and fat content.

Key words: Electrical stimulation, meat quality, Pesisir cattle, tenderness, protein content

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Development of the farming sector through enhanced productivity and quality is required to fulfill societal demands and improve social welfare. Meat has long been known to be an almost perfect food because it contains complete nutrients needed by the human body, including proteins, energy, water, minerals and vitamins. Aside from nutritional needs, most people tend to like meat due to its aroma and taste.

To improve its quality and quantity, it is necessary to consider all aspects relating to the productivity of cattle, especially the seeds of the livestock and the fodder as these greatly influence the quality and quantity of meat after the slaughtering process.

The quality of the carcass and meat are influenced by several factors before and after the slaughtering process. Some factors that influence the quality of meat before slaughter include genetics, species, animal class, types of cattle, sex, age, fodder including additive substances (hormonal, antibiotic and mineral) and stressful conditions. Factors that might occur after the slaughtering process include the aging, electrical stimulation, cooking technique, pH of the carcass and meat and additional supplements, including meat tenderizing enzymes. Electrical stimulation is a simple technology but it has a great economic influence on meat. For example, electrical stimulation of a carcass can increase its tenderness, maintain the pH and reduce cooking loss during storage[1]. Pesisir cattle are indigenous to West Sumatera, Indonesia. Our fattening program uses local feed resources resulting in an average daily gain 0.68 kg, dressing percentage of 52.67%, back fat thickness of 2.6 mm and rib eye area of 68.46 cm^{-2} [2].

Most people are unaware of issues related to the quality of meat, therefore, it may be difficult for them to acquire meat of good quality. The slaughter houses are aware of certain requirements before conducting the slaughtering process. These requirements include the following: (1) The cattle must be healthy based on a veterinarian's recommendation, (2) The cattle should not be in an exhausted condition, (3) Cattle that are no longer productive cannot be used as seed, (4) The cattle are slaughtered in an emergency situation[3].

The factors of meat quality that are related to eating focuses on tenderness, color, flavor and meat juiciness. Aside from these factors, the intramuscular fat, cooking loss, nutrient content, chemical characteristics and pH of the meat can also determine its quality. Some of the chemical characteristics include protein content, fat, dry materials and water content. Protein is mostly found in muscles and tissues.

Electrical stimulation hastens the onset and resolution of rigor mortis, thereby reducing processing time and labor and plays a vital role in improving meat tenderness and other meat quality traits. However, electric stimulation may have negative impacts on some meat quality traits such as color stability and water holding capacity in some animals. Electrical stimulation is not an end in itself. To achieve the desired benefits from its application, the technique must be properly used in conjunction with various intricate antemortem, perimortem and postmortem management practices[4].

Tenderness was significantly enhanced by electrical stimulation for the Longissimus thoracic muscle[1]. There is still limited information about the qualities of carcass and meat that are produced by local livestock and there are no studies that connect tissue structure to quality of meat. This situation prompted us to conduct comprehensive research on the quality of carcass and local livestock. This study aimed to investigate the interaction between voltage and duration of electrical stimulation on the quality of meat. The quality was assessed based on tenderness, protein content and pH of Pesisir beef. This study is expected to provide our society with information about current meat quality and the effectiveness of techniques to improve the quality of meat produced from Pesisir cattle.

MATERIALS AND METHODS

This study used beef from the *Longissimus dorsi* (LD) muscles of male Pesisir cattle that were 2.5-3 years old and with medium-sized bodies. A 2x3 factorial experiment was performed in a block. The first factor (A) was the voltage of electrical stimulation, which consisted of a1 = 110 volts and a2 = 220 volts. The second factor (B) was the duration of electrical stimulation, which consisted of b1 = 1 min, b2 = 2 min and b3 = 3 min. The days of taking samples were used as the blocks of this experiment. Samples were taken from slaughter houses and were kept in a refrigerator for 24 h. Subsequently, pH, tenderness, protein and fat contents were measured. The measured pH was considered to be the ultimate pH of the meat 24 h after the slaughtering process. Tenderness was measured as the power required to break meat fibers using the Warner-Bratzler shear force. The measurements of protein and fat contents were conducted based on AOAC[5]. The data were analyzed by using two-way analysis of variance. Duncan's multiple range test was used to determine significant differences between the means. Differences were considered significant at $p<0.05$.

RESULTS AND DISCUSSION

Tenderness: Average scores of Pesisir beef tenderness after electrical stimulation are presented in Table 1.

The average values of meat tenderness using Warner-Bratzler shear force procedure ranged from 5.32-6.34 kg cm^{-2}. There was no significant interaction between the voltage and duration of electrical stimulation of the meat. The averages tenderness of the beef with electrical stimulation at 110 and 220 volts were 5.99 kg cm^{-2} and 5.55 kg cm^{-2}, respectively (Table 1). The effects of the voltage of electrical stimulation on meat tenderness were statistically significant ($p<0.05$) and show that the higher the voltage, the lower the meat tenderness. This outcome means that the meat becomes more tender when we use the higher voltage of electrical stimulation. A carcass that receives electrical stimulation is more delicate than a carcass without electrical stimulation because the electrical stimulation loosens the muscle and weakened the collagen bonds[1]. A carcass that is shriveled and electrically stimulated will experience glycolysis expansion, a decrease in pH and faster enzyme activity, processes that tend to increase the tenderness of the meat[6].

Electrical stimulation can hasten postmortem glycolysis, prevent muscle shortening due to chilling temperature (also called "cold shortening") and increase meat tenderness of lamb. Similarly, it can improve the tenderness and flavor of beef[7].

The analysis of variance showed that the duration of electrical stimulation significantly increased tenderness. The average values of meat tenderness in beef that was electrically stimulated in one, two and three min were 6.10, 5.68 and 5.54 kg cm^{-2}, respectively. Statistical analysis reveals that the value of meat tenderness which was stimulated for 1 min was significantly lower than the that tenderness of meat which was stimulated for 2 and 3 min. There were no significant differences in the tenderness of meat as the effect of electrically stimulated for 2 and 3 min.

The increasing tenderness of Pesisir beef due to the longer duration of electrical stimulation does not represent a direct process but instead is a result of simultaneous chemical processes, electrical stimulation on Pesisir beef influenced glycolytic processes that resulted in higher pyruvate and lactate accumulation as well as the unraveling of fat structures. Electrical stimulation can influence glycolysis by rapidly changing one molecule of glucose to one molecule of pyruvate, two Adenosine triphosphate (ATPs) and two Nicotinamide Adenine Dinucleotide Hydrogen (NADHs). The ATP acts as a source of energy to activate and increase the study of proteolytic enzymes toward muscle protein[7].

Protein content: The average protein content of Pesisir cattle meat undergoing electrical stimulation treatment with different voltages and durations are presented in Table 2.

The protein content of Pesisir beef ranged from 18.83 to 19.34%. The statistical analysis showed no interaction between electrical stimulation voltage and the duration of electrical stimulation ($p>0.05$), however, the electrical stimulation voltage significantly decreased the protein content of Pesisir beef, while the duration of electrical stimulation had no significant influence. According to previous chemical analysis, the meat mainly consists of water (65-80%), protein (16-22%), fat (1.5-13%), non-protein nitrogen substance (1.5%), non-nitrogen carbohydrates 1.0% and inorganic constituents 1.0%. Concentrated fodder that is given to Pesisir cattle can increase the protein content of the beef[8].

The average protein contents of Pesisir beef that were electrically stimulated at 110 and 220 volts were 19.28% and 18.86%, respectively. The higher the voltage is, the lower the protein content will be. This tends to make enzymatic processes proceed faster. The degree of change in the meat texture is proportional to the amount of voltage of the electrical stimulant. Meat from a carcass that has been electrically stimulated will tend to have a loose muscle structure, due to the weak collagen bonds. It has also been revealed that electrical stimulation decreased protein because of the formation of lactic acid that lowers the pH of the meat[1].

pH: The average pH of Pesisir cattle meat by electrical stimulation treatment at different voltages and durations are shown in Table 3.

Results of the present study showed that the average pH value of Pesisir beef was between 5.56 and 5.63. The statistical analysis found no interaction between the voltage and the duration of electrical stimulation and unaffected on the pH of the meat. The ultimate pH (or final pH) is achieved when glycogen is no longer present in the meat. Thus, ultimate pH is influenced by glycolytic enzymes. The ultimate pH is achieved after the muscle glycogen becomes exhausted after the glycolytic enzymes become inactive at low pH or after glycogen is no longer sensitive to the attacks of glycolytic enzymes[9]. After the animal is slaughtered, the pH of the meat decreases and ultimate pH will be achieved 24 h later[7]. The decrease in pH occurs due to the cessation of blood flow that results in oxygen unavailability in the capture of liberated hydrogen ions during the process of glycolysis and the tricarboxylic acid (TCA) cycle[5].

Table 1: Average of Warner-Bratzler shear force of Pesisir beef by electrical stimulation treatment with different voltage and duration of electrical stimulation (kg cm^{-2})

	Duration of electrical stimulation			
Voltages	1 min	2 min	3 min	Average
110 volts	6.34	5.88	5.76	5.99[a]
120 volts	5.85	5.47	5.32	5.55[b]
Average	6.10[a]	5.68[b]	5.54[b]	5.77

Table 2: Average protein content of Pesisir cattle meat by electrical stimulation treatment with different voltage and duration of electrical stimulation (%)

Electrical stimulation	Duration of electrical stimulation			
voltages	1 min	2 min	3 min	Average
110 volts	19.34	19.29	19.21	19.28[a]
120 volts	18.92	18.83	18.83	18.86[b]
Average	19.13	19.06	19.02	19.07

Table 3: Average of pH of Pesisir cattle beef on different voltages and durations of electrical stimulation

Electrical stimulation	Duration of electrical stimulation			
voltages	1 min	2 min	3 min	Average
110 volts	5.63	5.59	5.60	5.61
120 volts	5.58	5.61	5.56	5.58
Average	5.61	5.60	5.58	5.60

Table 4: Average of fat contents of Pesisir beef with electrical stimulation treatment at different voltages and durations (%)

Electrical stimulation	Duration of electrical stimulation			
voltages	1 min	2 min	3 min	Average
110 volts	4.36	4.35	4.37	4.36[a]
120 volts	3.92	3.90	3.85	3.89[b]
Average	4.14	4.13	4.11	4.12

The normality of the final pH of meat after slaughtering is also caused by the depletion of energy reserves in the muscles due to electrical stimulation. In addition, before slaughter, the cattle arrested and then fasted for 12-18 h[7]. The pH value of the muscle after the animal is slaughtered will decrease from 7.4 (beginning) to 5.6-5.7 at the 6th h until the 8th h, then, the pH value will decrease further to a final pH of approximately 5.3-5.7 on the 24th h post-mortem[5].

Fat content: Current study found that the level of fat contents of Pesisir cattle meat that had undergone treatments ranged from 4.11-4.37%, values that are still within the normal range. Based on chemical analysis, meat consists primarily of water (65-80%), protein (16-22%), fat (1.5-13%), non-protein nitrogen substance (1.5%), non-nitrogen carbohydrate (1.0%) and inorganic constituents (1.0%) (Table 4).

No interaction was observed between the voltage and duration of electrical stimulation. The voltage of 220 lowered the fat content but the duration of electrical stimulation had no significant effect on the fat content of Pesisir cattle beef.

The decrease in the fat content of Pesisir cattle meat due to electrical stimulation was likely caused by the induction of electrical stimulation that causes the acceleration of glycolysis. Converting glycogen into glucose so that the production of pyruvic acid or lactic acid led to structural damage of the main components of Pesisir cattle beef, which ultimately also affected the beef's fat structure. Moreover, electrical stimulation delivers heat that leads to fat melting and decomposition. This process can significantly change the formation of flavor and aroma. In short, the higher the electrical stimulation voltage was, the more accelerated the process of glycolysis, which damages the structure and the main components of meat that cause the melting of fatty meat faster, thus, the fat content of meat decreases[10].

CONCLUSION

There is no interaction between the voltage and duration of electrical stimulation regarding tenderness, protein content and the pH of Pesisir cattle meat. Protein and fat content of Pesisir Cattle meats were lower with A2 treatment compared to A1 treatment, in otherwise increased tenderness. The

duration of electrical stimulation significantly increased tenderness but did not affect pH, protein and fat content.

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