Evaluation of Certain Electrical Parameters for Stimulating Lamb Carcasses

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Story in Brief

The efficiency of electrical stimulation at two voltages (50 V and 350 V) and three frequencies (10, 100 and 250 Hz) was evaluated on lamb carcass sides using direct current pulsed as a square wave with a 20 percent duty factor. The carcass sides were electrically stimulated within 15 minutes of bleeding using appropriate voltage and frequency for 4 minutes. All sides were kept in a 16°C cooler until the pH of the *Longissimus dorsi* (LD) and *Semimembranosus* (SM) muscles reached 6.0 and then transferred to a chilling room at 2°C. LD, SM and *Semitendinosus* (ST) muscles were used to study some physico-chemical changes. Stimulating lamb sides at 350 V and 10 Hz gave the fastest glycolysis (drop in pH) at 2 and 4 hours postmortem, and the period required to reach pH 6.0 was much shorter than achieved by stimulation with any other combination of voltage and frequency in LD and SM muscles. The energy output per pulse which was highest at 350 V and 10 Hz was the governing factor for glycolysis rather than the total energy output. Cold shortening was minimal in the ST muscle of electrically stimulated sides at 350 V and 10 Hz compared to the controls. In general, electrical stimulation, while reducing cold shortening, had no effect on lean color. Similarly, different protein fractions (Sarcoplasmic, myofibrillar and stroma proteins) were not affected by any combinations of voltage and frequency.

Introduction

There is ample evidence that postmortem electrical stimulation of carcasses of food animals provides many benefits. However, there appears to be much variation in the electrical parameters — type of current, voltage, frequency, pulse duration, pulse shape, etc. — used. In most cases a particular electrical stimulation condition was used empirically rather than based on any theoretical considerations. Voltages as high as 3600 and as low as 5 and frequencies ranging from 2400 Hz to 5 Hz were used. It is likely that a relationship between electrical parameters like voltage and frequency exists for accelerating postmortem muscle glycolysis. Such a relationship has not been studied previously on intact carcasses. This study was conducted to investigate the effect of electrical stimulation of lamb carcasses at different voltages and frequency levels on some biochemical and quality characteristics of lamb muscles.

Materials and Methods

Two voltage levels, 50 and 350 volts, and three frequencies, 10, 100 and 250 Hz, within each voltage were used to stimulate Suffolk lamb carcasses. The lambs

were slaughtered, skinned, eviscerated and divided into sides (carcass weight 19 to 25 kg.) The sides were randomly assigned to electrical stimulation within 15 minutes postmortem. Two electrodes were applied, one at the neck near the 5th and 6th cervical vertebrae and the other at the muscular portion of the achilles tendon. A direct current with a square wave pulse at the designated voltage and frequency was applied to each carcass side in a cooler at 16°C for 4 minutes. The physical response of the muscles during stimulation was observed and recorded. Samples from LD and SM muscles were taken for measurement of pH. Internal temperature of intact LD and SM was recorded at 0, 2, 4, and 24 hour postmortem, the same time at which pH was measured. The extent of cold shortening was measured on ST muscle strips, and the lean color was measured using a Hunterlab tristimulus colorimeter and recorded as L, a, b values. The ratio of redness to yellowness was calculated. The solubility of different protein fractions (sarcoplasmic, myofibrillar and stroma protein) was studied. Samples from the homogenous LD muscles were extracted sequentially with different buffer systems using protein extraction apparatus.

Results and Discussion

Based on visual observations, the cervical and thoracic regions of the sides flexed more vigorously in a lateral direction when stimulated at a high voltage (350 V) than at a low voltage (50 V). Most of the muscles on the carcass surface exhibited fast twitching at low frequency (10 Hz) without regard to voltage; however, twitching continued for a longer period at the low voltage. At 250 Hz the whole side went into tetanic contraction without showing any twitching of individual muscle at both the voltages.

How fast the postmortem muscle pH drops to 6.0 has been used as a criterion to determine the effectiveness of electrical stimulation in accelerating glycolysis. Significant differences in time for the LD and SM to reach pH 6.0 were observed when carcass sides were stimulated at 350 V and 50V, and the frequency varied from 10 to 250 Hz as shown in Figure 1. Stimulation at 350 V and 10 Hz provided the shortest time for the muscles to reach pH 6.0, while other stimulation treatments required more time; yet they were significantly different from the controls for both the LD and SM muscles. Frequency also had an effect in reducing the time for the muscle to reach pH 6.0. Low frequency was more effective. This study provided evidence that frequency, along with voltage, increases the rate of postmortem glycolysis in muscles due to stimulation.

Stimulation of the sides with 350 V resulted in a much higher total energy output than at 50 V. A change in frequency from 10 to 250 Hz had little effect on the total energy output. The output energy per pulse decreased as the frequency was increased. The decrease in jules per pulse was also affected by voltage. Electrical stimulation at 350 V and 10 Hz provided the greatest energy ouput per pulse. The energy per pulse was markedly lower at 50 V and further decreased with an increase in frequency.

Electrical stimulation at 350 V and 10 Hz caused the greatest pH drop in the LD and SM muscles at the 2 and 4 hour poststimulation periods. At 24 hour postmortem the ultimate pH of the muscles was not significantly different between treatments. The pattern of postmortem temperature changes of intact LD and SM muscles at 0, 2, 4, and 24 hour poststimulation was not significantly different at any given time among treatments.

Electrical stimulation had a significant influence on the potential of Ca^{++} induced shortening of muscle. High voltage (350) had a greater effect than

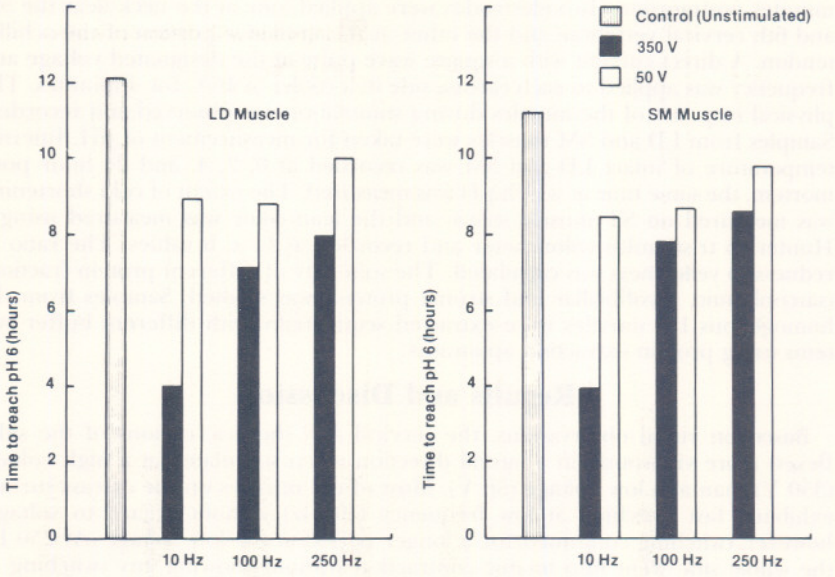

Figure 1. Time required to reach pH for intact LD and SM muscles as affected by electrical stimulation at different voltages (V) and frequencies (Hz)

stimulation at a low voltage (50 V). At 50 V, the frequency had no effect on the shortening of the ST whereas at 350 V different frequencies exhibited a significant effect (Figure 2). The excised ST muscle from the carcass side which was stimulated at 350 V and 10 Hz experienced the least shortening. The postmortem release of Ca^{++} from the sarcoplasmic reticulum and (or) from the mitochondria at the time that the adenosine triphosphate (ATP) level in muscle is still high results in a significant level of cold shortening. However if the Ca^{++} is released after some depletion of ATP from muscle has taken place, only a minor amount of shortening occurs. It is known that electrical stimulation causes rapid depletion of ATP, which is the primary source of energy for the cold shortening. This study suggested that stimulation of carcasses at 350 V and 10 Hz resulted in a more rapid depletion of the energy source from muscle than the other treatments.

Lean color of the muscle, measured and calculated as L, a, b values and the a/b ratio, which is an indicator of redness, was not significantly different among the treatments. Similarly, the protein solubility of different fractions of muscle proteins was not affected by electrical stimulation with any of the combinations of voltage and frequency.

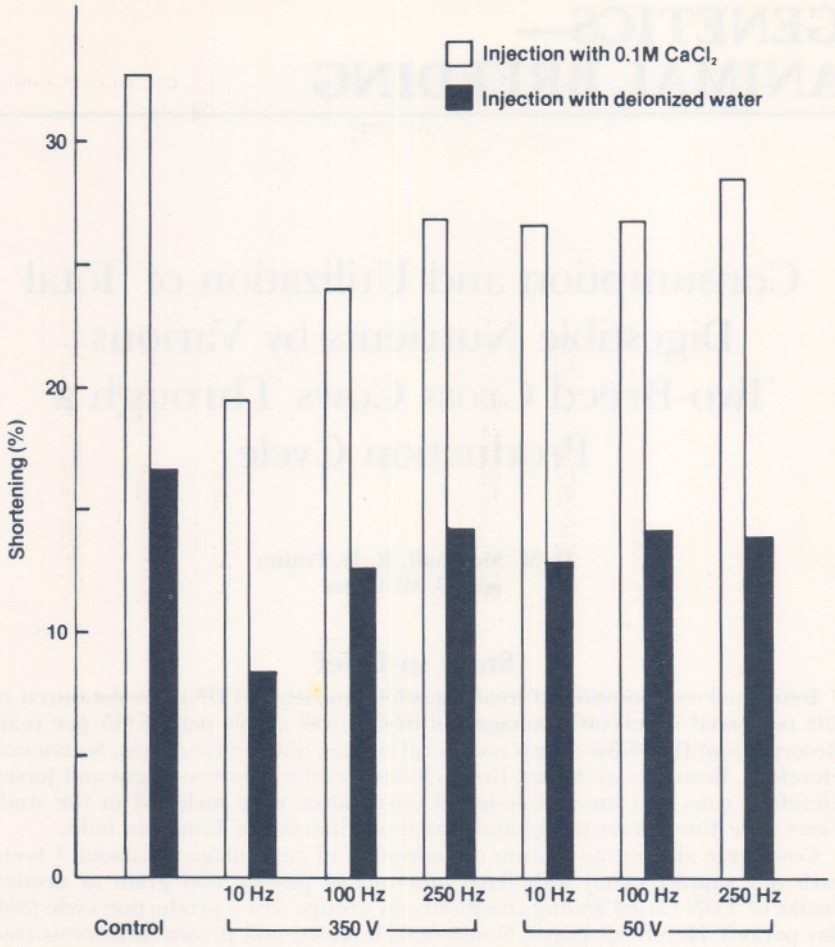

Figure 2. The effect of electrical stimulation at different voltages (V) and frequencies (Hz) on the extent of shortening of ST muscle strips