The potential for a combination of stretch and electrical stimulation technology to optimise hot-boned meat quality

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Abstract

Hot-boned meat is commonly tough due to rigor shortening. Imposing meat to a combination of stretch and electrical stimulation immediately after hotboning may prevent rigor shortening through an increased rate of glycolysis. This experiment assessed how combinations of stretch and electrical stimulation changed the force of muscle contraction (increased force corresponds to an increased rate of glycolysis) that could be obtained at 90min post anoxia (likely time for hotboning) using an in-vitro muscle strip preparation. Data indicates that there is an optimal level of tension which will elicit a maximal force of contraction in the sheep muscle strips at 90 mins post anoxia and this is different between muscles. Therefore each muscle/cut will need to be individually assessed for its optimal tension level. Force generated can be further increased by manipulating voltage and pulse width. There is a negative effect of excessive force exertion. Our results show that it is the degree of tension exerted that determines the force generated when the muscle is stimulated, not the degree of stretch of the muscle. This has commercial implications with regard to how stretch/stimulation technology is applied and what the controlled variables are as it will be critical to control of tension exerted rather than length stretched.

Introduction

Hot boning of beef and sheep carcasses has distinct advantages over cold boning. This includes more rapid processing, less effort to bone and the potential for improved yield. Further, expensive chilling of fat and bones is avoided. However hot boning has the potential to produce tough, dark irregularly shaped meat. The increased risk of toughness is due to the potential development of cold shortening. Cold shortening is the result of a contraction of the sarcomere caused by the release of calcium, whilst ATP is still available, from the stimulus of decreasing temperature (Tornberg 1996). At the colder temperatures the sarcoplasmic reticulum becomes less efficient at reabsorbing the released calcium and therefore the muscles stay contracted and sarcomeres shorten (Honikel et al. 1983). This condition can be avoided if the rate of glycolysis and therefore ATP utilisation is increased. Significant advantage could therefore be gained for the meat industry if the rate of glycolysis in hotboned cuts could be increased.

Electrical stimulation within 90 min of slaughter is well within the time frame of processing hot-boned products and the subsequent contractile response may increase glycolysis and reduce the potential for cold shortening. With the correct degree of stretch, a much greater response to the same stimulation can be produced, although if muscle fibres are stretched too far, the degree of overlap between thin and thick filaments decreases and crossbridges that are not overlapped by thin filaments cannot bind to actin, and therefore cannot contribute to force generation (Germann 2004). The combination of electrical stimulation and stretch may therefore be a useful mechanism to increase contractile force at 90 mins – i.e. with the correct degree of stretch, a much greater response to the same stimulation can be produced.

The aim of this objective was to determine the maximum increase in force of muscle contraction that could be obtained at 90min post mortem using various combinations of stretch and electrical input.

Materials and methods

Sheep (Merino crossbred lambs, mixed sex) were commercially slaughtered and dressed. The semitendinosus (ST) and semimembranosus (SM) muscles were immediately removed and immersed in Krebs solution (Schroder et al. 1997) at room temperature. Longitudinal strips of skeletal muscle were dissected from the outer surface and medial edge of the SM and ST muscle. Strips (avg 17mm, 0.2g, length was measured before mounting weight after) were mounted vertically in organ baths (110ml capacity) containing Krebs solution at 34°C aerated with 5% CO2 in 95% O2 (pH 7.4). The Krebs solution had the following composition (mmol/L): NaCl 120.0, KCl 5.0, CaCl2 2.5, Na2HCO3 25.0, MgSO4 1.0, NaH2PO4 1.0, and glucose 22.0, equilibrated with 5% CO2 in O2 (for oxygenated solution) or 5% CO2 in N2 (for anoxic solution, to give pH of 7.4. A resting tension of 1g was applied to each strip, which was then equilibrated for ~30min. Mechanical activity was recorded isometrically with a force transducer (FT.03, Grass Instruments, Quincey, MA) and a Powerlab Chart Recorder (ADInstruments USA). Muscle strips were

stimulated transmurally with stainless steel electrodes 5mm apart connected to Grass stimulators. Electrode polarity was optimised with 1sec of 2Hz, 0.5 msec and 20V pulses. The experimental procedure is described in Figure 1.

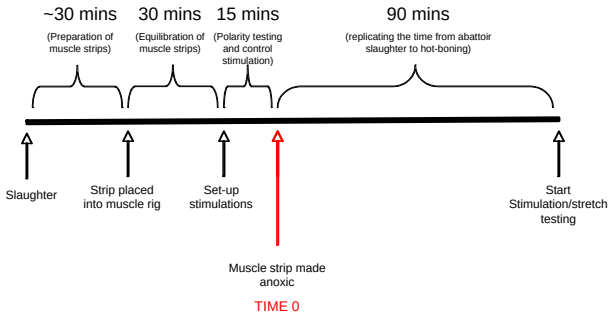

Figure 1. Experimental procedure for stretch and stimulation experiments.

Following equilibration, and before the use of the test parameters, the muscle strips were stimulated with 80Hz, 0.1ms and 60V to provide a control twitch for each strip as an internal control for each individual organ bath. For the 90 min post-anoxic period, the muscle was set with a resting tension of 1 gram. Various combinations of stretch (1g, 2g, 4g, 6g, 8g) and stimulation parameters (1 or 5 ms pulse width, 60 or 100V voltage) were then applied. Tension (weight applied) is referred to as tension exerted. The contractile response is referred to as force generated. Results have been modeled using a General Linear Model (SAS).

Results and discussion

Stimulation at 90 mins from time of anoxia can still result in a force generation but there is a decrease in force generation with increased time from anoxia. There is a tension exerted (weight applied) that will elicit a maximal force generation in the muscle strips at 90 mins post slaughter. This maximal levels occurs irrespective of level of voltage or pulse width administered. Maximal force generated (optimal response) is obtained at 3.5g of tension for ST and 4.5g of tension for SM (Figure 2A). There was a significant interaction between tension exerted and muscle type indicating that the effect of tension on force of contraction is different for different muscle types (Figure 2A). There is a negative effect of excessive force exertionn that results in a decrease in force generated. Fast twitch muscles such as the ST show a greater loss in potential force generated with time.

There was a significant interaction between muscle type and both voltage and pulse width indicating that different muscle types respond differently to different voltage and pulse widths (Figure 2B and C). At the optimal tension exerted, the amplitude of force generated can be modified by altering electrical parameters such as voltage and pulse width. An increase in both voltage and pulse width will increase force generated. The use of higher levels of stimulation may therefore be a strategy to further increase glycolysis and ATP utilisation through work done, thereby maximising pH decline.

There was a significant relationship between length of the muscle strip and the force generated (Figure 2D and 2E)) with the longer the strip the greater the force generated, when corrected for weight. Weight, when corrected for length, is not significant, therefore it is the actual length of the muscle that determines the force generated at a particular tension exerted. In other words, it is the tension exerted that determines the subsequent contractile response, not the amount of stretch applied to the muscle.

There was a significant interaction between time from anoxia and pulse width indicating that stimulation with higher pulse widths under anoxic conditions will result in a slower rate of decline in force generation (Figure 2F). The results show a 66% decline in force of contraction from 90 to 340 mins from anoxia for the 1ms treatment compared to 20% decline for the 5ms treatment. Further experimental work is required to optimise the stimulation settings for individual muscle/cut/primal.

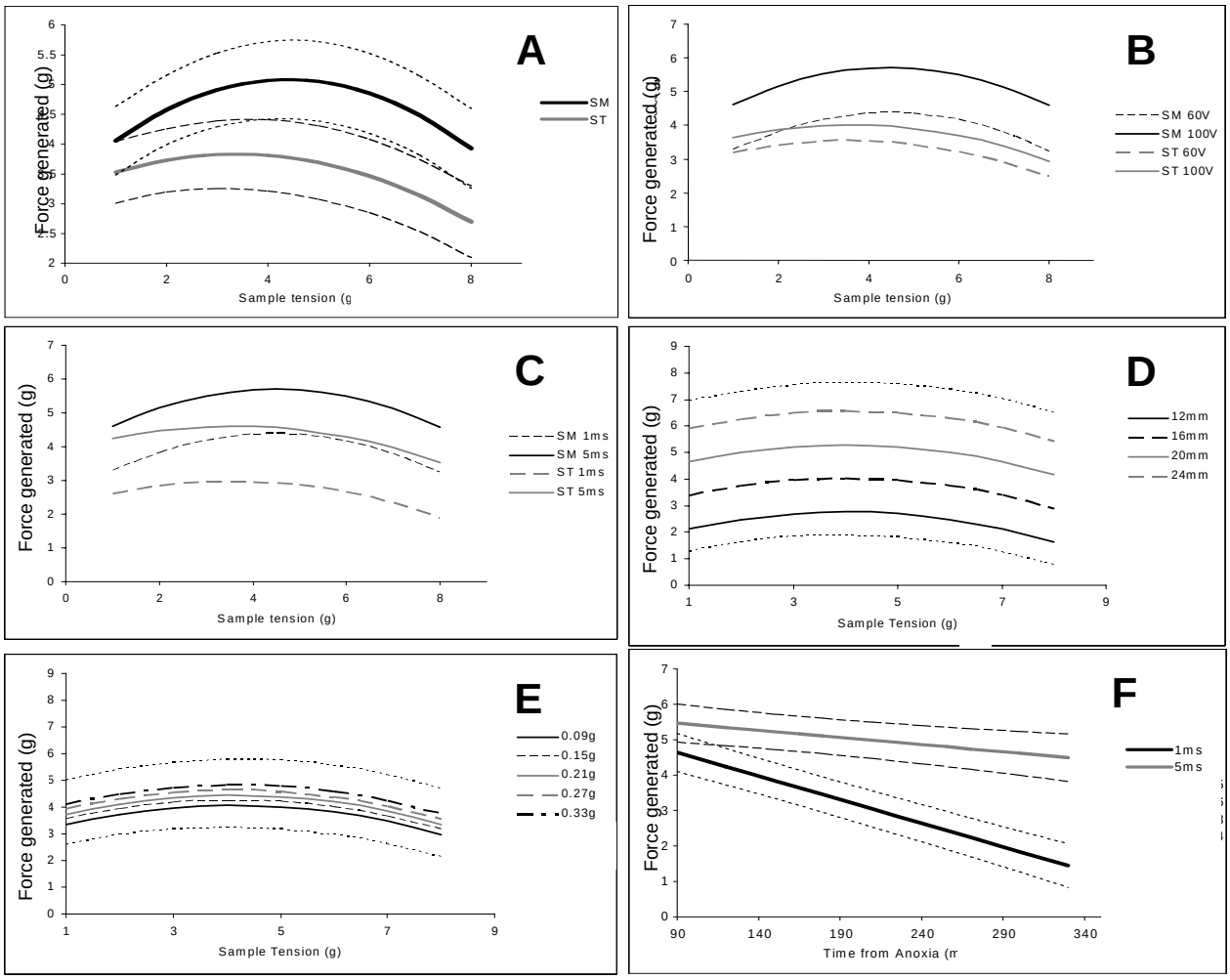

Figure 2. The effect of tension applied on force of contraction (g) for different muscles (SM and ST) (Figure 2A), effect of tension at at different voltages (Figure 2B) and different pulse widths (Figure 2C), the effect tension at different muscle lengths (Figure 2D) and weights (Figure 2E) on force of contraction, the effect of pulse width on force of contraction with an increase in time from anoxia (Figure 2F). Values are least mean squares regression lines with +/- standard errors for Figures 2C-2F.

Conclusions

This study has indicated that incorporating a stimulation and stretch component into a hot boning scenario may be a highly productive option to improve meat quality. Force generation can be increased using different levels of tension, sample length and electrical parameters The issue arises of how the results obtained with the muscle strips in an in-vitro experimental setting can be transferred to whole muscle/cut or primals.

To apply these technologies on a commercial level it will be necessary to define an optimal tension/stretch level for each muscle/cut/primal. We have shown that an optimal level of tension exists which will elicit a maximal force of contraction in the muscle strips at 90 mins post anoxia. The level of tension is the same regardless of voltage, pulse width, muscle length or time from anoxia. However, a higher force of contraction and therefore a faster pH decline could be improved using optimised electrical stimulation parameters for voltage and pulse width.

Hot boning and application of stretch/stimulation technologies needs to be applied as soon as possible after slaughter as force of contraction declines with time. The use of higher pulse widths may be a strategy to counteract for the negative effect of time on force of contraction.

Tension exerted determines the force generated, not the degree of stretch of the muscle. We suggest that such technologies that are able to control the tension exerted rather than stretch the muscle bodies to a predetermined length.

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