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Combined Effects of Electrical Stunning and Stimulation on Post Mortem Glycolysis in Lambs.

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INTRODUCTION

The major aim of stunning animals before slaughter is to produce immediate insensibility of sufficient duration to ensure that the animals will not regain sensibility during slaughter and subsequent bleeding. Other important factors to be considered in relation to the selection of a suitable stunning and slaughter technique are simplicity and safety of operation, effects on carcase contamination, capital and running costs of equipment and effects on meat quality (Blackmore and Petersen,1981).

In many countries, sheep and lambs are stunned by a captive bolt whereas in New Zealand electrical methods of stunning have been widely adopted. Initially, such electrical methods consisted of application of electrodes to the head only. However, the majority of meat works are now using electrical methods which cause concurrent cardiac inhibition by application of electrodes to both the head and body. These are colloquially known as "head-to-back" and "head-to-leg" methods and both produce permanent insensibility which allows time for oesophageal ligation before the actual slaughter process. Such methods can be operated at relative low costs, are well suited for high rates of production and are now being automated, thereby increasing operator safety. It has also been possible to eliminate most of the associated carcase defects although subcutaneous haemorrhagic speckling still appears to be a problem of some significance (Petersen and Wright,1979; Thornton et.al.,1979).

At the same time as these methods of electrical stunning were being developed, the meat industry introduced various methods of electrical stimulation of carcases. Such techniques have the effect of increasing post mortem glycolysis of muscle and thereby allow holding times between slaughter and freezing to be reduced without the occurrence of cold shortening. All methods of stunning and slaughter causes involuntary muscular movement, and therefore some degree of glycolysis, which varies according to the method employed. The effects of such terminal muscular activity on post mortem muscular glycolysis has received comparatively little attention in the past and only a few studies have been reported (Pearson et.al.,1973; Shorthose, 1978; Chrystall et.al.,1981). These studies were all carried out on small groups of experimental animals and may therefore not completely reflect circumstances which occur at the meat works.

The present studies were carried out to gain more precise information on the type and amount of muscular activity associated with different methods of stunning and slaughter and the effects of such activity on the rate and decline of the pH of muscle post mortem.

MATERIALS AND METHODS

All the studies were carried out at meat export works where groups of lambs from within the same line were subjected to different methods of stunning and slaughter during normal operating procedures. Although selection of the animals into different treatment groups could not always be achieved on a strictly random basis, care was exercised to assure that groups within the same line were comparable with respect to carcase weights and grades.

The following methods of stunning and slaughter were used :

(a) Transverse incision of the ventral neck region with severance of the major vessels, the trachea, the oesophagus and the spinal cord at the occipito-atlantal junction, i.e. the gash-cut method traditionally used without prior stunning in New Zealand up to 1977.

(b) Stunning by penetrating captive bolt followed by severance of the major vessels within the thoracic inlet, i.e. the thoracic stick described by Blackmore and Newhook (1976).

(c) "Head-only" electrical stunning (0.75-1.25 A, 50Hz for 2-3s) with two electrodes on the head using a "Paralec" stunner* followed by slaughter as in (a).

(d) Electrical "head-to-leg" stunning using the same electrical parameters as in (c) but with a third electrode connected to metal rails in contact with the lower part of the limbs ("Paralec Split-Stun System")*. This was followed by thoracic stick as in (b).

(e) Same method of stunning and slaughter as in (d) but immediately after stunning, the lambs were subjected to "Quickage"* low voltage electrical stimulation (50-150mA at 24V for approximately 90s). This was achieved by suspending the animals by all four legs between two isolated rails, and while suspended the animals were slaughtered.

The muscular acitivity of animals following stunning and subsequent slaughter was recorded by two observers and, where possible, the duration of specific events were timed. After dressing, inspection and grading, all carcases were transferred to holding areas where the ambient temperatures were approximately 20°C. In the first series of studies, muscle tissue samples (two to three grams)were obtained from the M.longissimus dorsi by the method previously described (Petersen, 1982). All samples were kept under liquid paraffin at room temperature until processed in the laboratory where one gram of muscle tissue was homogenised in 10ml of 5mM neutral iodo-acetate in water and the pH of this solution was measured using a combination glass electrode.

In the last study, the pH values of lambs stunned by a captive bolt and by an electrical "head-to-leg" method were compared at intervals during a 24 hour period. The carcases were transferred from the holding area to a chiller approximately four hours after slaughter. The temperature in the chiller was approximately 15°C at the time of loading and declined to 12-13°C during the next few hours and remained at this temperature for the rest of the study period. In this study, the pH values were obtained by direct probe methods using a combined type Lot 406-M4 Ingold pH electrode**. The probe was inserted at a depth of approximately 15mm in the lumbar region of the right M.longissimus dorsi. Subsequent measurements were taken from a different site but in close proximity to the first.

RESULTS AND DISCUSSION

The reactions of the animals to different methods of stunning and slaughter are recorded in Table 1. Both methods of electrical stunning caused tonic contraction of all skeletal muscles which lasted for approximately 25 seconds. This is the characteristic tetany seen as the animals emerge from the conveyor and is followed by a two to four minute period of clonic spasms characterised by intermittent leg and body movements. The extent and duration of such movements appeared to be slightly increased in those animals stunned by the "head-only" method as compared to those stunned by the "head-to-leg" technique.

Animals stunned by a captive bolt also exhibited tonic spasms but of much shorter duration (approximately 15 seconds). This was followed by intermittent leg and body movements for up to four minutes which appeared to be of a more vigorous nature than those seen in animals which had been electrically stunned. However, the most vigorous leg and body movements were observed in lambs slaughtered without prior stunning but tonic spasms did not occur.

In Table 2, a comparison is made of post mortem pH values of the M.longissimus dorsi between animals stunned by the "head-to-leg" method and those slaughtered by three other methods. It can be seen that pH values at three hours after slaughter are constantly lower in the animals stunned by the "head-to-leg" method as compared to other groups. These differences were significant in all groups apart from one comparison between a group stunned by a "head-only" method and a group stunned by a "head-to-leg" method. It would therefore appear that "head-to-leg" stunning increases the rate of post mortem glycolysis as compared to other methods.

It has been shown by Devine et.al., (1979) that increases in glycolysis can be produced both indirectly through intact nervous pathways and by direct stimulation of muscles. Both methods of electrical stunning investigated would presumably induce a degree of both direct and indirect stimulation of muscles. The former being associated with the field effects of the stunning current. However, it would seem likely that there would be more direct stimulation of muscles when the "head-to-leg" method is used as the distance between the electrodes applied to the animal's body is greater. This effect is likely to be exacerbated under the commercial conditions studied where the animals were sprayed with water and restrained in a stainless steel conveyor which also acted as a body electrode. Thus the direct stimulation of muscles by the "head-to-leg" method is probably the major cause of the increased rate of post mortem glycolysis in animals stunned by this method. This hypothesis is also supported by further unpublished studies which indicate that muscle from shorn and very damp lambs had significantly lower pH values shortly after slaughter than muscles from woolly, dry lambs stunned by the "head-to-leg" method. This finding could be explained by the reduced conductivity of the fleeces of the latter group and therefore less direct stimulation of muscle.

Animals stunned by a captive bolt or slaughtered without prior stunning are only subjected to indirect stimulation through nervous pathways and it is therefore not surprising that the pH values shortly after slaughter were always significantly higher than the corresponding groups stunned by the "head-to-leg" method.

The effect of low voltage stimulation for 90 seconds during the slaughter and bleeding process on rate and decline of muscle pH is shown in Figure 1. It can be seen that in three separate comparative trials there was a highly significant difference in early pH values of stimulated and non stimulated carcases. On average the pH of stunned and stimulated carcases from the three study groups had declined to a value of 6.0 within two hours whereas the pH of stunned, non stimulated carcases had only declined to approximately 6.3 and non stunned, non stimulated carcases (one group only) had a mean of 6.4 at the same time. There were no significant differences between the ultimate pH values in any of the groups.

The rate of decline of pH during a 24 hour period of lambs stunned with a captive bolt and by an electrical "head-to-leg" method is shown in Figure 2. It can be seen that at the time of the first measurement (90m), the pH of the electrically stunned animals (6.42) was significantly less than those stunned with a captive bolt (6.66). This difference of approximately 0.2 of a pH units, remained the same for the next seven and a half hours, but by 15 hours after slaughter the pH measurements of both groups were similar. Figure 2 also indicates that the animals stunned by a captive bolt took three hours longer to reach a pH of 6 as compared to electrically stunned lambs. However, the increased rate of glycolysis in the electrically stunned animals responsible for this more rapid decline, had occurred during the early part of the pre-rigor period and was not due to an increased rate of glycolysis throughout the period.

The effect of electrical stunning by a "head-to-leg" method on post mortem glycolysis would thus appear to be of only short duration and although subsequent low voltage stimulation of carcases caused a dramatic decrease in pH values one hour after slaughter, this effect also appeared to be of short duration as the differences between stimulated and non-stimulated groups were of the same magnitude one and two hours after slaughter. This is in contrast to high voltage (3600V) electrical stimulation which has been reported to cause both an immediate decline in pH values as well as in increased rate of glycolysis resulting in pH values declining to 6.0 within one hour after slaughter (Chrystall and Hagyard, 1976).

Although high voltage electrical stimulation has proved to be a very effective method of producing a tender product, it is believed that a combination of stunning by a "head-to-leg" method with low voltage electrical stimulation could become a beneficial alternative for some meat works. This particular method of stunning is well suited for the present methods of dressing and the low voltage electrical stimulation completely immobilises the animals during subsequent slaughter and bleeding operations and thereby enhances operator safety. The present findings indicate that using this method of slaughter, pH values can be expected to be below 6.0 within two hours of slaughter. Thus a period of delay of two to three hours from slaughter to freezing of carcases may be sufficient to avoid cold shortening of meat. If thaw shortening is to be avoided, slightly longer periods may be required or else carcases would need to be conditioned at sub-zero temperatures.

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Table 1 : Muscular reactions of lambs to different methods of stunning and slaughter

Method of stunning and slaughter	No. of animals observed	Delay between stunning and slaughter	Detectable heart beat at slaughter	Duration of tonic spasms Mean ± S.E.(sec)	Severity of clonic body movements *
(a) no stun, transverse cut	12	n.a.	+	0	very vigorous movements
(b) captive bolt, thoracic stick	24	app.1-1½ min	+	14.6 ± 0.84	vigorous movements
(c) el."head-only", transverse cut	12	5-10 sec	+	25.0 ± 0.92	some intermittent movements
(d) el."head-to-leg" thoracic stick	23	app.1-1½ min	-	26.3 ± 0.75	very little movement

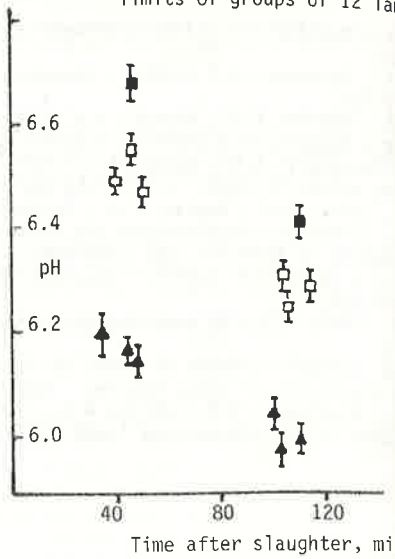
* some intermittent leg movements were noted in all animals for up to three minutes after slaughter.

Table 2 : pH values three hours after slaughter and stunning by "head-to-leg" method compared with three other methods of slaughter.

Alternative Method	No.in group	Mean ± S.E.	"Head-to-leg" No.in group	Mean ±S.E.	Sample Variance Ratio (F_s)
(a) No stun					
Group A	12	6.28±0.022	12	6.19±0.027	5.77*
Group B	12	6.28±0.020	12	6.19±0.031	5.40*
(b) Captive bolt					
Group C	21	6.35±0.021	24	6.27±0.015	9.01**
Group D	14	6.28±0.016	14	6.15±0.032	11.68**
(c) Electric "head -only"					
Group E	12	6.28±0.023	12	6.19±0.038	4.01
Group F	15	6.36± 0.032	15	6.27±0.026	4.54*

* = significant of the 5% level
** = significant at the 1% level

Figure 1 : Decline of muscle pH during a two hour period (means and 95% confidence limits of groups of 12 lambs)



■ No stun; transverse cut,no stimulation
□ Electrical"head-to-leg" stun,throacic stick, no stimulation
▲ Electrical"head-to-leg"stun,thoracic stick, low voltage stimulation

Figure 2 : Decline in pH in lambs stunned by either captive bolt or electrical "head-to-leg" method (16 animals per group).