MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

1/11 – January 2011

Effect of slaughter method on animal welfare and meat quality

- **Although all stunning procedures are not totally comfortable from the animal's point of view, penetrative stunning is less noxious and more effective in inducing insensibility when compared to high power non-penetrative stunning and low power non-penetrative stunning.**
- **Subjecting animals to unstunned slaughter followed by penetrative stunning is more stressful than high power non-penetrative stunning and low power non-penetrative stunning.**
- **High power non-penetrative stunning and unstunned slaughter followed by penetrative stunning resulted in inferior meat quality in cattle.**
- **Thoracic sticking can improve meat quality.**

The manner in which livestock are mustered, yarded, handled, transported, restrained, slaughtered, and exsanguinated can affect their welfare and final meat quality. Welfare requirements dictate that animals should be insensible to noxious, potentially painful, stimuli during slaughter. In abattoirs, pre-slaughter stunning is usually applied to induce rapid desensitisation of animals to the pain of slaughtering, and to minimise bodily injury risks to abattoir personnel. This is important as the neck region contains a number of sensory nerve fibres that are capable of triggering powerful reflex reactions upon throat cut; therefore, stunning should be done effectively. This minimises the possibility of animals regaining consciousness, and renders the animal insensible during the throat cut. The insensibility should last until total cessation of vital signs. Stunning procedures in cattle include the use of electrical and mechanical (penetrating and non-penetrating) stunning. Electrical stunning in cattle, however, has been associated with blood speckle and blood splash in the carcase. With mechanical stunning, the intent is to cause concussion with or without penetration. The power of the mechanical stunner can be adjusted to suit the size of the animal handled.

For the application of religious slaughter, where certain modes of stunning are acceptable, it is mandatory that stunning should be reversible. The throat cut, itself, should be the cause of death. Some Muslim authorities accept non-penetrating mechanical stunning of cattle, but not penetrating captive-bolt stunning. The basis for this is that non-penetrating stunning is recognised to be 'reversible' while penetrating stunning is considered to be 'non-reversible'. Nevertheless, head injuries to cattle caused by non-penetrating stunning can be severe.

The impact of the stunner head against the relatively thin frontal bone, which forms the roof of the cranium in cattle, can result in severe, well-circumscribed, depressed fractures of the skull with subarachnoid haemorrhage in the brain below. In some countries, non-penetrative mechanical stunning is not allowed because of a risk that insufficient power could result in an ineffective stun and, therefore, compromise animal welfare. The potential for error in performing the non-penetrative mechanical stunning is a major welfare concern.

Earlier studies suggested that cutting the throat fails to sever the vertebral arteries supplying the brain. This may prolong duration of sensibility following slaughter. Interruption of the blood supply through the vertebral arteries in cattle may be achieved by severance of the brachiocephalic trunk by the use of a 'thoracic stick'—an incision with a knife through the thoracic inlet. Thoracic sticking, which severs the brachiocephalic trunk near the heart, is reported to have resulted in greater rate of blood loss than that following bilateral neck severing. The thoracic sticking intervention is widely practised, and is commonly associated with enhanced bleeding and a hastened death process.

This Update discusses the effects of different mechanical stunning methods—high power non-penetrative mechanical stun (HPP), low power non-penetrative mechanical stun (LPP), penetrative mechanical stun (P), unstunned slaughter followed by penetrative mechanical stun (US)]—and thoracic sticking —low power non-penetrative stunning followed by thoracic sticking (LPPS) and penetrative mechanical stunning followed by thoracic sticking (PS)—on stress-related hormones, meat quality and electroencephalographic reactions in beef cattle.

Stress-related hormones

When discussing stress, the nervous and endocrine (hormone) systems are of primary focus. External and internal stimuli are channelled via the nervous system to the hypothalamus in

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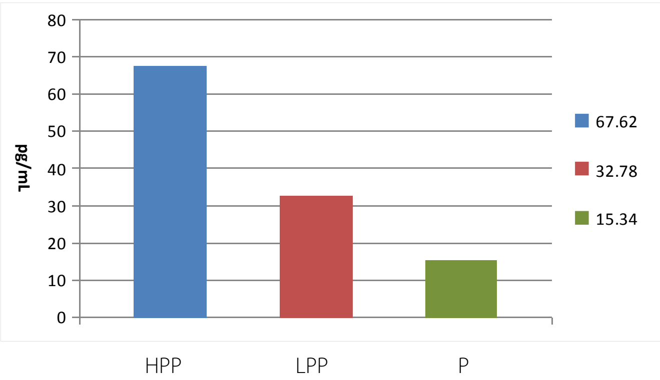

Figure 1. *Plasma adrenalin concentration following stunning.**

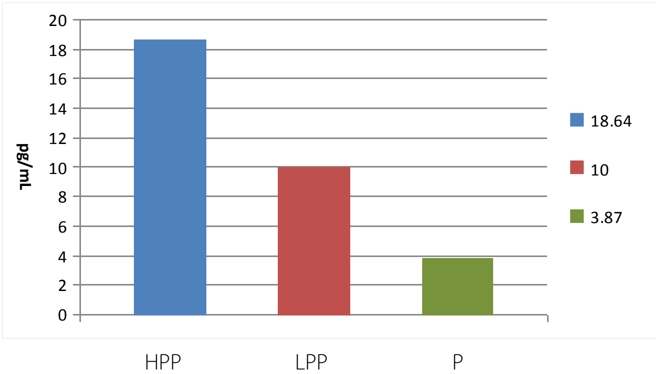

Figure 2. *Plasma ACTH concentration following stunning.**

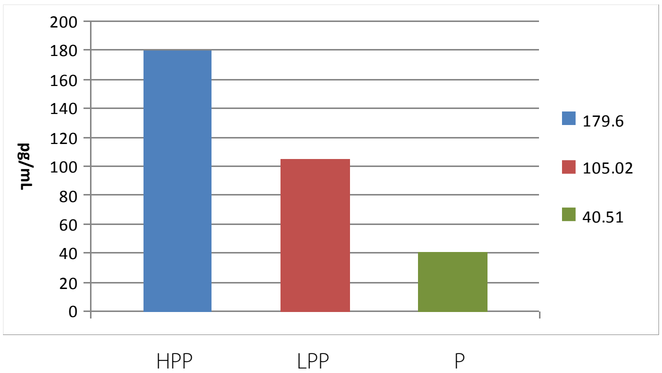

Figure 3. *Plasma noradrenalin concentration following stunning.**

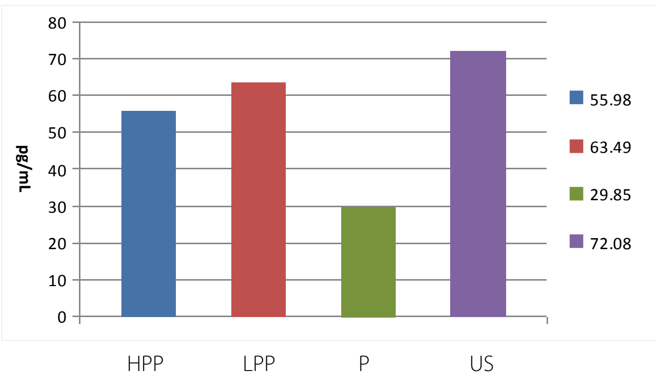

Figure 4. *Plasma adrenalin concentration following slaughter.**

** HPP = high power non-penetrative stunning; LPP = low power non-penetrative stunning; P = penetrative stunning; US = unstunned slaughter followed by penetrative mechanical stun*

the brain. Once a stressor has been perceived, two distinct pathways involving interlocking physiological reactions are evoked. The first pathway encompasses nervous stimulation of the adrenal system which is responsible for elevation in circulating adrenalin and noradrenalin or the 'flight or fight' mechanism. Although this system may have a dramatic physiological impact, it is short term. When it fails to cope with the stressor(s), the second pathway—hormonal system—is induced, and circulating adrenocorticotrophin hormone (ACTH) and corticosteroids will increase. These stress-related hormones may evoke glycogenolysis which is closely associated with muscle changes in stressed cattle.

Penetrative mechanical stunning (P) caused smaller increases in plasma adrenalin concentration (Figure 1) when compared to the HPP and LPP groups, suggesting animals experienced less distress. Although the purpose of stunning is to eliminate animal suffering during the slaughter procedures, as measured by plasma levels of ACTH (Figure 2) and noradrenalin (Figure 3), HPP induced a greater physiological stress reaction when compared to P. Earlier studies suggested that, although both P and HPP resulted in similar structural tissue damage, focal injury was more severe in the former, while the latter caused more widely distributed damage. Penetrative captive bolt stunning was more effective, and the likelihood of error was lower than for non-penetrative stunning.

It has been shown that following a throat cut, blood clots can form in the carotid arteries. This occlusion of the arteries can lead to a delay in the onset of insensibility due to alternative blood supply to the brain via the vertebral arteries. Thoracic sticking improves bleeding and negates the effect of carotid occlusion by rapidly draining the blood from a point in the circulatory system prior to the entry to the vertebral arteries. With effective stunning, thoracic sticking is not a welfare concern. The thoracic-sticking procedure had negligible effect on stress-related hormones.

Throat or neck cut without prior stunning is a major welfare issue in many countries. Whether the animal suffers pain during the neck or throat cut has been the subject of much debate. The adrenalin data indicated that animals subjected to P were least distressed during slaughter when compared to HPP, LPP and US (Figure 4). The results show that the penetrative stunning procedure can be a good method to stun cattle because it is less stressful to cattle and effective in reducing the noxious sensory input caused by the neck cut. Although the circulating adrenalin data suggested that US was more stressful than P, there is little evidence that the former caused more stress to the animals during slaughter than HPP and LPP.

Meat quality

Stress associated with improper pre-slaughter handling of livestock has been associated with undesirable pH, water-holding capacity, cooking loss and colour. Tenderness—as the most variable and important determinant in meat eating quality—along with the degree of lipid oxidation are among the traits of major concern in the meat industry. What happens to the animals prior to slaughter usually influences the physiological state, particularly energy metabolism of the skeletal muscle. This, in turn, affects the post-mortem muscle metabolism whereby most of the meat-quality characteristics are eventually attained. However, differences in metabolic and contractile characteristics between different groups of skeletal muscles also explain most of the differences in post-mortem changes and ultimate meat quality as a response to the physical activity and stress experienced by the animal pre-slaughter.

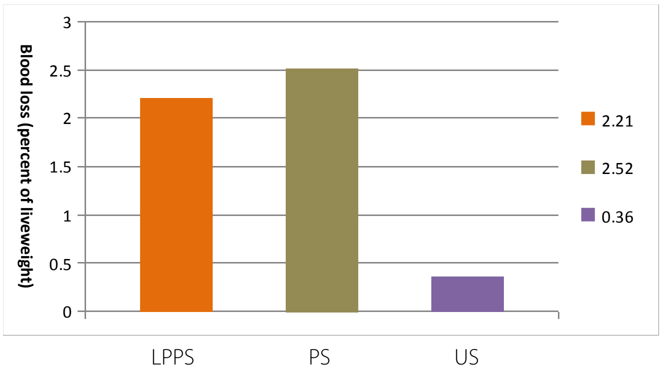

Figure 5. *Percentage of blood loss per live weight following stunning and thoracic sticking.^*

^LPPS = low power non-penetrative stunning followed by thoracic sticking; PS= penetrative percussive stunning followed by thoracic sticking; US= unstunned slaughter followed by penetrative mechanical stun

Generally, meat from HPP and US cattle had higher cooking loss, lower water-holding capacity (WHC), greater degree of lipid oxidation, poorer colour values and high peak force values (tougher). The adverse effects on meat quality resulting from the application of HPP were found to be more apparent and consistent in the *Semitendinosus* (ST) than in the *Longissimus dorsi* (LD) muscle. The resulting lower WHC following HPP stunning could be explained by earlier onset of rigor due to more rapid glycolytic changes caused by the more stressful slaughtering conditions experienced by the animals. The early breakdown of muscle glycogen usually leads to an earlier pH drop which, if occurring at high carcase temperature, can lead to denaturation of muscle proteins—a state where the polarity of proteins and ability to bind water molecules are usually disrupted.

Lipid oxidation in muscle starts immediately after death, following the failure of the circulatory system and the cessation of metabolic activities. It has been associated with deterioration in the quality of meat. It is well accepted that stress and handling of animals during slaughter influence the degree of lipid oxidation in meat. The use of HPP resulted in a higher level of thiobarbituric acid reactive substances (TBARS) which indicates greater lipid oxidation in the muscles.

The application of P improved tenderness of the ST muscle. The reason why only the ST muscle was affected by the stunning could be explained by the differences in metabolic and contractile properties between both muscles. It is well accepted that the ST muscle is mainly involved in locomotion and exercise during pre-slaughter handling. Thus, the response given—by both muscles as a result of different pre-slaughter and slaughter condition—could also be influenced by their activities.

Most of the colour values (L*, a*, b*, hue and chroma) of both muscles remained unaffected by the various stunning methods; however, they appeared redder (greater a* value) when the animals were subjected to thoracic sticking following the application of LPPS and PS stunning. Furthermore, penetrative stunning followed by thoracic sticking (PS) also reduced cooking loss and lipid oxidation while improving water-holding capacity and tenderness. The lowered TBARS level highlights the benefits of PS in reducing lipid oxidation in beef. This could be explained by the higher percentage of blood loss following LPPS and PS, compared to unstunned slaughter followed by penetrative stunning (US) (Figure 5). The findings further support earlier reports that residual blood in the carcase and meat determine their stability and shelf life.

Electroencephalography response

Electroencephalography (EEG) can be used in conjunction with stress hormone measurements in blood and physical observation, to monitor the presence of pain and stressful changes. EEG waveforms could also provide information on the effectiveness of stunning. The presence of low frequency delta waves, which occurred in HPP, LPP and P animals, is frequently associated with anaesthesia and unconsciousness in an animal with intact vital signs, and is suggestive of an effective and survivable stunning procedure. Conversely, the presence of large intervals of higher frequency alpha and beta brain waves, which usually occur in conscious animals, suggest stressful conditions related to post-slaughter pain; however, it should also be noted that delivery of the stunning force could also induce massive cellular and signal disruption, resulting in EEG changes that should be taken into account during interpretation. While animals subjected to P had the lowest alpha and beta wave intensity immediately post-stunning, and at 30 seconds after throat cut compared to both LPP and HPP animals (Figure 6), the converse was noted for US animals. This could possibly be explained by the animals' awareness of pain or other stressful factors attributed to the slaughtering procedure.

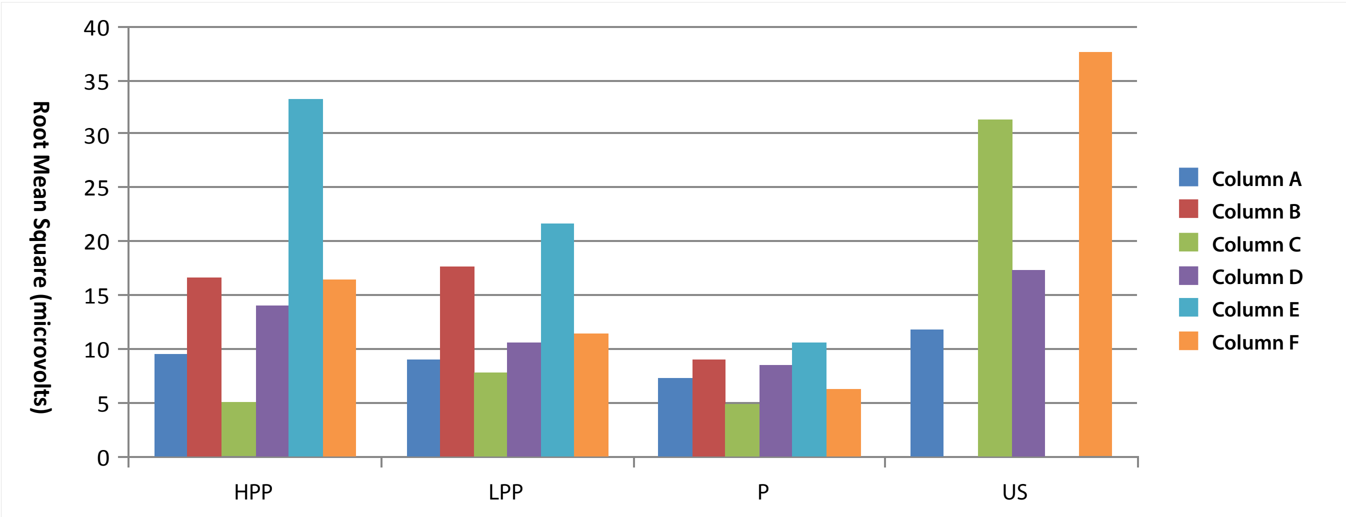

Figure 6. *Alpha & Beta waveform changes (µV) according to stunning method*

A: Pre-stunning alpha; B: Immediate post-stunning alpha; C: 30s post-slaughter alpha; D: Pre-stunning beta; E: Immediate post-stunning beta; F: 30s post-slaughter beta

The delta wave activities typically spiked immediately post-stunning (Figure 7), consistent with the expectation that animals are in a state of unconsciousness following stunning. The alpha and beta waves from the HPP and LPP animals spiked rapidly post-stunning, but declined gradually to their respective terminal values. Coupled with the appearance of low frequency waves within the frequency range of theta and delta waves in all stunned animals, it was concluded that stunning did render the animal unconscious, and less able to perceive noxious stimuli compared to the animals that were subjected to post-slaughter stunning. However, it should be noted that HPP animals probably experienced a significant amount of post-stunning brain excitation, possibly due to tissue damage—as evidenced by the appearance of higher beta wave intensity readings immediately after stunning. On the other hand, the lower beta and alpha activities among LPP and P animals immediately after stunning is suggestive that these animals probably experienced much less post-stunning brain excitation. Penetrative stunning seemed to be the best at maximising the possibility of post-stunning insensibility, while the US animals seemed to demonstrate an increase in EEG activities consistent with the presence of post-slaughter noxious stimuli associated with tissue cut and injury. Because the US animals were also subjected to penetrative stunning immediately after throat cut, the spike in EEG activities at 30 seconds after throat cut could be attributed to the additive effects of both throat cut and stunning. If post-slaughter stunning resulted in more 'suffering' to the animals, one could ask whether the procedure is necessary. However, researchers in New Zealand recently demonstrated that effective post-cut stunning would eliminate any pain responses shown on EEG.

The time post-slaughter to attain terminal or lowest possible EEG values —or 'Terminal Time'—for all waveforms, has been used in conjunction with the absence of vital signs, such as corneal reflex, to determine the point of cessation of brain electrical recordings; however, stunning is not expected to affect the duration from throat cut to the point when the brain stopped producing significant amount of electrical signals. This study clearly showed that stunning method was not a significant contributor to hastening Terminal Time, or cessation of all visible vital signs and reflexes, as well as cerebral functions.

In general, the inclusion of thoracic sticking during slaughter did little to change the EEG waveform intensity across all methods of stunning included in this study. In fact, thoracic sticking did little to shorten the Terminal Time, or time taken for EEG waveform reading to achieve its lowest reading accompanied by the absence of vital signs. This suggested that thoracic sticking was not a significant contributor to hastening the disappearance of vital signs and reflexes, but merely responsible for the rapid suppression of brain activity which probably placed the animal in a state of deep unconsciousness prior to the cessation of vital signs.

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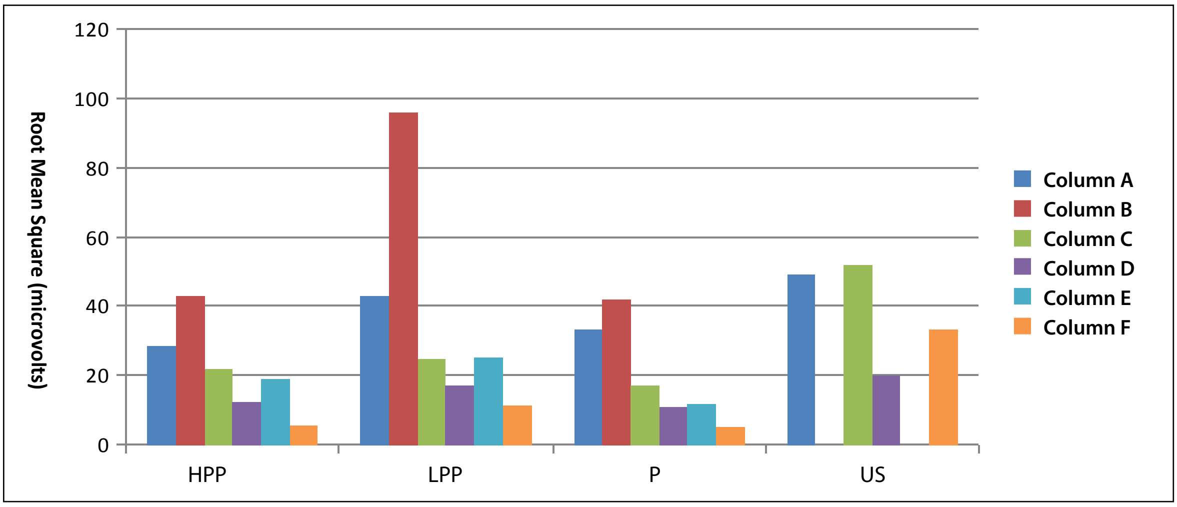

Figure 7. *Delta & Theta waveform changes (µV) according to stunning method*

A: Pre-stunning delta; B: Immediate post-stunning delta; C: 30s post-slaughter delta; D: Pre-stunning theta; E: Immediate post-stunning theta; F: 30s post-slaughter theta

Contact us for additional information

Meat Industry Services is supported by the Australian Meat Processor Corporation (AMPC) and Meat & Livestock Australia (MLA).

Brisbane:
CSIRO Food & Nutritional Sciences
PO Box 745
ARCHERFIELD QLD 4108

Neil McPhail
T +61 7 3214 2119
F +61 7 3214 2103
M 0414 336 907
Neil.McPhail@csiro.au

Armidale:
Alison Small
CSIRO Livestock Ind.
Locked Bag 1
ARMIDALE NSW 2350
T +61 2 6776 1435
F +61 2 6776 1333
M 0409 819 998
Alison.Small@csiro.au

Sydney:
Bill Spooncer
PO Box 181
KURMOND NSW 2757
T +61 2 4567 7952
F +61 2 4567 8952
M 0414 648 387
bill.s@bigpond.net.au

Melbourne:
Robyn Warner
Private Bag 16
WERRIBEE VIC 3030
T +61 3 9731 3268
M 0407 316 760
Robyn.Warner@csiro.au

Adelaide:
Chris Sentance
PO Box 344
LYNDOCH SA 5351
T +61 8 8524 4469
M 0419 944 022
chrisfss@ozemail.com.au