The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK
www.ufaw.org.uk

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Electromagnetic induction of insensibility in animals: a review

A Small*†, D McLean‡, JS Owen§ and J Ralph#

† CSIRO Livestock Industries, FD McMaster Laboratory, Locked bag 1, Armidale, NSW 2350, Australia
‡ Advanced Microwave Technologies, University of Wollongong, Building 42, Northfields Avenue, Wollongong, NSW 2500, Australia
§ PO Box 5227, Manly, QLD 4179, Australia
# Wagstaff Cranbourne Pty Ltd, 15 Moorakyne Avenue, Malvern, VIC 3144, Australia
* Contact for correspondence and requests for reprints: Alison.small@csiro.au

Abstract

The prevention of unnecessary suffering at slaughter is considered to be an imperative and, as such, the majority of animals slaughtered under industrial conditions are stunned prior to slaughter by mechanical, electrical or gas inhalation means. However, many Orthodox Jewish and Muslim communities do not accept pre-slaughter stunning. Those Jewish and Muslim communities that do accept pre-slaughter stunning require that any such stun is fully reversible in order to meet the requirements of their religious laws. Head-only electrical stunning is widely used in sheep, as it is a reversible method of stunning, but in cattle, the stun duration can be so short that the animal may regain consciousness during exsanguination. The concept of using electromagnetic radiation to induce insensibility has been proposed. Early attempts to induce insensibility and death in laboratory species were successful, but the technology to apply the technique to larger animals was not available at that time. More recently, however, technological advances have led to new work in the areas of transcranial magnetic stimulation and microwave irradiation, both of which are potential methods of inducing a recoverable stun in larger species.

Keywords: *animal welfare, cattle, humane slaughter, livestock, recoverable stun, stunning*

Introduction

Animals as meat have long provided an important source of dietary protein to human beings. It is understood that we have an obligation to care for the animals and ensure that the process of slaughter is carried out in such a way as to minimise suffering. The earliest written guidelines on care of animals and slaughter are found in the religious texts of the *Torah* (the *Pentateuch*, the most sacred writings of Judaism) and the *Qur'an* (the Muslim scripture). One of the most important aspects in these texts is the requirement that the animal must be alive, undamaged and healthy at the point of slaughter. Furthermore, the texts stipulate the manner in which the animal shall be slaughtered — a single rapid cut of the throat, using an extremely sharp knife. This method of slaughter is the fundamental requirement of Jewish and Muslim communities around the world, otherwise the meat produced is considered unclean and unsuitable for human consumption.

Notwithstanding the strict requirements of these religious texts, a need for improving welfare of slaughtered animals has led to the development of methods of rendering the animal insensible or unconscious prior to the cutting of the throat. Throughout the past century and longer, the process of slaughtering animals for human consumption, except for some Jewish and Muslim markets, has included pre-slaughter stunning, as described in regulations and guidelines, such as the OIE Terrestrial Animal Health Code, the European Regulation EC 1099/2009, the Australian Primary Industries Standing Committee Model Code of Practice for the Welfare of Animals: Livestock at Slaughtering Establishments and in USDA regulations 9 CFR Ch III Part 313. A number of the methods of stunning available have been accepted by some Jewish and Muslim markets in certain parts of the world, on the proviso that the stun is fully reversible, and the animal would recover fully if the throat was not cut, ie the stun does not render the animal dead. For example, head-only electrical stunning, which is fully recoverable, is widely used in sheep slaughter globally. In this method, an electric current is passed through the brain, resulting in insensibility with brain activity similar to that seen in an epileptic fit. However, when applied to cattle, electrical head-only stunning has met with a degree of criticism, particularly in terms of the duration of stun, which may not be long enough to allow death to occur as a result of blood loss prior to the stun wearing off.

Wotton *et al* (2000) stunned two-year old cattle using currents of 0.86 to 1.70 Amps and recorded the return of rhythmic breathing as an indicator of a return to consciousness. They found that the tonic phase duration varied from 2 to 21 s; the clonic phase ended 30 to 102 s

after stun induction, and rhythmic breathing returned by 31 to 90 s after stun induction. From this, they concluded that operators may find it very difficult, in a commercial situation, to hoist and stick the animals prior to the onset of the clonic phase. Furthermore, there is evidence that the vertebral circulation can maintain brain perfusion for up to 3 min following neck sticking of calves (Anil *et al* 1995), while Gregory *et al* (2010) recorded time to collapse of up to 265 s following neck cutting in cattle. Evidently, if a head-only electrical stun has worn off by 31 s, and brain perfusion can be maintained for 3 min or more, it is possible that animals may be regaining consciousness while still bleeding out.

In Australia, non-penetrating percussive mechanical stunning is allowed by the Australian, Malaysian and Indonesian Muslim markets. However, there is some concern that percussive stunning may not comply with the requirement for the animal to be undamaged at the time of slaughter, because the impact of the stunner can cause skull damage and contusions in the brain (Finnie 1995; Finnie *et al* 2000, 2003). Therefore, there is a need to investigate alternative reversible methods of stunning that can achieve consistent induction of insensibility of a duration that allows death through exsanguinations, and also complies with the requirements of not inflicting damage and being fully recoverable.

Recently, there has been interest in electromagnetic induction of insensibility in animals, using techniques such as transcranial magnetic stimulation (TMS), and microwave energy. This paper reviews the literature regarding electromagnetic induction of insensibility in animals.

Transcranial magnetic stimulation for induction of insensibility

TMS uses the principle of electromagnetic induction to generate electrical impulses within the subject's brain, by exposing the brain to a changing magnetic field. The technique is used in psychiatric therapy to induce seizures in patients, or to treat depressive conditions (Lisanby 2002; George 2003). TMS has been proposed as a method of inducing insensibility in animals (Anil & Butler 2002), and more recently it has been successfully demonstrated in a preliminary trial on 20 broiler chickens (Lambooij *et al* 2011). Here, the authors recorded electroencephalogram (EEG) and behavioural indicators of insensibility (tonic phase, clonic phase, muscle flaccidity and recovery with righting reflex) of chickens exposed to TMS at 35 or 50 Hz. The EEG traces showed evidence of insensibility and a dominance of theta and delta waves while, behaviourally, the birds were flaccid, and the duration of unconsciousness was calculated to be in the range of 15 to 20 s.

Microwave induction of insensibility

The electromagnetic field required for induction of insensibility may also be generated using microwaves (electromagnetic radiation of frequencies between 300 MHz and 300 GHz), and indeed conceptual microwave stunning methodologies have been described (Schwartz 1974, 1976; Takamura & Ishida 1997; Horst & Garcia-Rill 2007; Ralph *et al* 2011).

Microwave irradiation is an accepted method of euthanasia of laboratory rodents (Anon 2001), and microwave heating is commonly used to inactivate enzymes and fix brain tissue for histological purposes (Moroji *et al* 1977). Suggested microwave energy inputs for this application in mice are 3.2 kW for 1.1 s (Cosi & Marien 1998) and 2.5 kW for 0.68 s (Nordgren *et al* 1985), resulting in a brain temperature of 75–90°C. In rats, Delaney and Geiger (1996) used 10 kW for 1.25 s to achieve a brain temperature of 85°C, while Ikarashi *et al* (1984) used 10 kW irradiation at 2,450 MHz to achieve a brain temperature of 90°C in less than 900 ms in rats, and Zeller *et al* (1989) also euthanised chickens in less than 1 s using microwave irradiation at 2,450 MHz.

Notwithstanding the utility of microwave irradiation for euthanasia, it is likely that controlled irradiation can induce a reversible stun. There is a dearth of information on the temperature tolerance of living tissue, and it may be that the tolerances vary between species and between tissues. Thermal unconsciousness, such as that induced by exercise heat stress or fever, is reported to occur when core body temperatures reach between 40 and 45°C (Ohshima *et al* 1992), and as a rule of thumb, living tissue can withstand a temperature of up to around 50°C, after which tissue damage will occur (SB Butler, personal communication 2010). Thus, if microwave energy can be applied in such a way that insensibility is induced, but tissue damage is prevented, recovery will ensue. For humane slaughter purposes, the insensibility should be of a duration that allows death through exsanguination prior to recovery. If death does not occur, there may be an issue relating to prolonged brain hyperthermia, which could result in brain tissue damage, and an inability of the animal to recover fully. However, it appears that the maximum thermal tolerance of nervous tissue lies in the range of 40–60 min at 42°C, or 10–30 min at 43°C (Sminia *et al* 1994), whereas death through exsanguination occurs within 4 min or less in cattle (Newhook & Blackmore 1982; Gregory *et al* 2010).

Experimental work has shown that, using 2 to 10 kW of 915 MHz microwave radiation, rats could be stunned (Guy & Chou 1982). It was demonstrated that the animals would be unconscious after a brain temperature rise of 8°C and would remain unconscious for 4 to 5 min post exposure. Consciousness was regained when brain temperature returned to within 1°C of normal values. Also, Lambooy *et al* (1989) successfully induced unconsciousness in rats using a low-power microwave (2 kW): application for 1.5–2.0 s resulted in unconsciousness in 100% of the rats tested.

A number of patents have been filed regarding the use of microwaves for stunning of pigs and poultry (Schwartz 1974, 1976; Werner Wacker 1976; Takamura & Ishida 1997), while Lambooy *et al* (1989) irradiated six heads of slaughter pigs with microwaves of 434 MHz, and extrapolated their data to estimate the power output of a microwave generator that would be required to stun pigs within 1 s (45 to 70 kW). Similarly, CSIRO scientists (R Rankin, personal communication 1986) carried out laboratory investigations in the 1980s on sections of sheep heads in order to

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estimate the power required to increase brain temperature by 8°C. They estimated that an effective stun could be induced using power levels of 31.9 kW at 2,600 MHz or 61.6 kW at 3,350 MHz.

Further development of the concept was not pursued by these researchers since, at that point, suitable high-power microwave generators were yet to have been developed to accurately focus the energy, and neither did suitable shielding exist to ensure operator safety in a commercial situation. However, the recent patent filed by Ralph *et al* (2011), and research into microwave induction of insensibility of sheep (Small *et al* 2013; this issue) suggests that these technological issues no longer pose a problem, and research into the potential use of microwave energy to induce a recoverable stun may now be warranted.

Animal welfare implications and conclusion

There has long been much debate between the desire for pre-slaughter stunning for animal welfare reasons, and the requirements of some Jewish and Muslim communities for the animal to be able to recover fully from any such stun if it was not exsanguinated. Head-only electrical stunning seems, at present, to be the only stunning method that achieves this requirement, but there may be problems relating to duration of stun when applied to cattle. Recent developments in the field of electromagnetic induction of insensibility indicate that these technologies may deliver effective and reversible stunning that will meet the requirements of the religious texts and good animal welfare practice.

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