Scientific commentary: Carbon dioxide (CO\textsubscript{2}) for the stunning of pigs

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This document focuses on the welfare implications of using carbon dioxide (‘CO\textsubscript{2}’) as a method of stunning in commercial abattoirs for pigs. This document does not cover other stunning methods, other species, on-farm euthanasia, ethical or economic considerations.

**Humane slaughter.** Humane slaughter implies minimal pain and distress on an animal before it is killed. Various factors can influence pain, fear and distress in abattoir settings including the previous experience and breed of the animal, facility design, handling techniques, and the stunning and killing methods.

**Stunning.** In Australia, stunning of the animal is a legislative requirement (AS 4696: 2007, Sub-clause 7.10) mandated to induce insensibility, defined as the incapability to experience any feeling or sensory experiences, and thus ensure that the animal cannot feel pain and remains so until death. Different stunning methods can be used depending on factors such as the species and age of the animal, animal welfare and worker safety, practicality and economic considerations. For pigs, the most common stunning methods are inhalant gas (CO\textsubscript{2}), electrical stunning, or to a lesser extent penetrating mechanical method (captive-bolt stunning).

**CO\textsubscript{2} stunning process.** A commercial CO\textsubscript{2} stunning system for pigs typically consists of a loading pen, where pigs are transferred onto ‘gondolas’, usually in groups. The gondola is then lowered into a pit which contains between 80-100% CO\textsubscript{2} at the bottom. Because CO\textsubscript{2} is heavier than air, the pigs inhale increasing concentrations of CO\textsubscript{2} as the gondola is progressive lowered into the pit. Exposure of pigs to high concentrations of CO\textsubscript{2} (>80% by volume in air) leads to metabolic acidosis, reduction in intracellular pH, and as a result induces gradual loss of consciousness and sensibility (Martoft et al., 2002). Nevertheless, effects can vary in intensity and duration depending on several factors, most notably gas concentration, speed and duration of exposure (Raj and Gregory, 1996, Velarde et al., 2007).

**Advantage and disadvantage of CO\textsubscript{2} stunning.** The main welfare advantage of gas stunning over electrical and mechanical stunning is that pigs can be moved in groups, which is closer to their natural behaviour and reduces pre-slaughter handling stress in comparison to other stunning methods where pigs are typically moved into a single file and possibly with a restraining device. The main disadvantage of CO\textsubscript{2} stunning is that it does not induce instantaneous insensibility and exposure to CO\textsubscript{2} at concentrations high enough to induce insensibility is aversive to pigs.

**Time to loss of consciousness.** Loss of posture occurs in the range of 17 to 22 seconds after the start of CO\textsubscript{2} exposure (Raj 1999; Velarde et al., 2007). Using neurobiological measures, Martoft et al (2002) found a gradual suppression of brain processes from the very start of CO\textsubscript{2} exposure and Raj et al (1997) found total elimination of brain activity by 32 seconds. However, Rodriguez et al (2008) reported a significant reduction in brain processes 60
seconds after CO₂ exposure. The ascertained time to loss of consciousness is still debated (Tolo et al., 2010), and remains a methodological challenge for slaughter in general. Note that studies investigating measures of brain activity are often conducted in research settings, hence likely with minimal distress, as compared to studies assessing loss of posture, reflexes and behaviour in commercial settings where there is potentially higher variability in handling stress or other factors.

**Behavioural reaction under CO₂ exposure.** There is a large variation in pigs’ reaction to CO₂, from none to violent attempts to escape and vocalisations (Raj and Gregory, 1996; Velarde et al., 2007). Carbon dioxide has the potential to cause distress, and exposure to CO₂ concentrations higher than 30% are considered aversive to pigs (Raj and Gregory, 1996). Concentrations above 80% are usually considered more aversive but do have the advantage of a shorter time to loss of consciousness (Raj and Gregory, 1996; Velarde et al., 2007). Whether expediency can compensate for aversiveness in determining what is a humane slaughter method remains ethically debatable. Nevertheless, all gas mixtures investigated to date (the most tested alternatives being Argon and Nitrogen) involve some degree of aversiveness (Dalmau et al., 2010; Rault et al., 2013), and can require longer time to loss of consciousness (Raj, 1999; Llonch et al., 2012). There is ongoing research assessing the practicality and efficacy of gas alternatives.

**Factors possibly influencing stunning.** The discussion on welfare around slaughter is sometimes reduced to the stunning and killing methods. Nevertheless, fear and distress can occur throughout the procedure from unloading to death. Poor handling prior to slaughter, mixing of pigs or overcrowding can induce distress (Terlouw et al., 2008). In fact, electric shocks from a prodder are more aversive to pigs than exposure to 60% or 90% CO₂ (Jongman et al., 2000). There is anecdotal evidence that distressed animals are more resilient to anaesthesia. Proper handling by stockpeople and facility design are of paramount importance to animal welfare (Hemsworth and Coleman, 2011). There is also evidence that the higher reactivity of some pigs may have genetic basis, either due to breed or the halothane gene in particular (Velarde et al., 2007). Finally, regular monitoring of the stun quality is a requirement with any stunning method, including CO₂ stunning chamber (Atkinson et al., 2012), so that issues with the stunning process (including animal handling) can be promptly recognised and remedied.

**Conclusions.**

- The use of CO₂ is considered a humane and acceptable method of stunning pigs in Australia (Model Code of Practice for the Welfare of Animals: Livestock at Slaughtering Establishments, 2001), the United States (AMI, 2010), the European Union (EFSA, 2013) and by the World Organisation for Animal Health (OIE, 2005).
- Gas stunning offer the advantage of minimising handling stress by managing pigs in groups.
- Concentration (> 80%) and time of CO₂ exposure are critical. The time to full loss of consciousness remains contentious.
- Carbon dioxide is aversive to the pig. All gases investigated to date involve some degree of aversiveness and can require longer time to loss of consciousness.
- Handling procedures can be more aversive than CO₂ *per se*, emphasising the importance of proper handling and minimising pre-slaughter handling stress.
- CO₂ stunning, as other stunning methods, is only part of an overall slaughter system. Handling, animal genetics and experience, facility design, stunning and killing methods all can affect animal welfare during the slaughter process.
References


