A Review of the On-Farm Killing of Neonate Pigs and Poultry.

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Neonate pigs and poultry are killed on the farm for a variety of reasons that include, when they have reached an appropriate slaughter weight for human food production, when they are suffering with no likely prospect of recovery, when they are mortally injured, or when they are considered either economically or physically unviable (FAWC, 2017). It is important to protect the welfare of these animals to ensure that the method used to end their life does not cause pain or distress particularly if they are already suffering.

NEONATE PIGLETS

The AVMA Guidelines for the Euthanasia of Animals: 2013 Edition include the following methods for suckling pigs (neonate piglets): CO_2; Ar, N_2 and CO_2 mixtures; CO; inhaled anaesthetics; purpose-built non-penetrating captive bolt; electrocution (for pigs over 10 lb); anaesthetic overdose; and blunt force trauma.

Lethal Injection: A veterinarian can administer a lethal injection to kill the animal provided the carcass is not destined for human or animal consumption but this will have cost implications for the owner in terms of veterinary fees and cost of disposal. This method might also require additional manual restraint and result in a longer time to loss of consciousness than a captive-bolt device or free-bullet.

Inhaled Agents: Inhaled agents such as carbon dioxide, carbon monoxide, nitrogen, or argon have been designated by the AVMA (2015) as conditionally acceptable. However, the use of inhaled agents requires the provision and maintenance of suitable containers for animals, a supply of gas cylinders and control equipment, e.g. Euthanex.com; Livetec Systems Ltd. The exposure of livestock to high concentrations of CO_2 has been shown to be aversive (Raj and Gregory, 1995; FAWC, 2003; Sandilands, et al., 2011) and should be avoided wherever possible (FAWC, 2017). Exposure of the piglets to carbon dioxide in groups, in a container with up to 80% CO_2, is a method that can be applied in commercial settings but does have animal welfare implications. CO_2 is known to produce a strong aversive response in the induction phase in all species, which on average lasts for approximately 15 seconds when pigs are exposed to high concentrations of CO_2 before the onset of anaesthesia (Raj, et al., 1997). Anaesthesia is produced by metabolic and respiratory acidosis, increasing the acidity of the cerebrospinal fluid leading to neuronal dysfunction. Experiments have demonstrated that the aversion to CO_2 is such that pigs will avoid a food reward, even when fasted for up to 24 hours, if the CO_2 concentration is above 80% (Raj and Gregory, 1995). The 80% CO_2 in air mixture appeared to be more aversive for pigs than 15% CO_2 in N_2 or 30% CO_2 in Ar, as indicated by earlier occurring retreat attempts. This may be explained by the lower CO_2 content in the latter mixtures (Dalmau et al., 2010; Llonch et al., 2012). A mixture of 90% Ar in air appeared least aversive, but was slower to induce a loss of standing posture (Dalmau et al., 2010) and is much more difficult to maintain on-farm.

Pigs are also known to show aversion (escape attempts) when the rate of induction of unconsciousness is slow (e.g. during exposure to 40 to 70% by volume of CO2 in air) and will demonstrate signs of respiratory distress at ≥40% (Raj and Gregory, 1996). Rodríguez, et al., (2008) concluded that pigs demonstrate excitatory movements during the induction of anaesthesia and that these excitatory movements represent conscious movement, indicative of aversion to the gas.

When piglets that are already compromised due to injury or disease are collected in batches, they are generally kept alive until sufficient numbers have been identified to warrant the use of CO_2. When placed in the container prior to the addition of the gas those animals at the bottom of the container are likely to be suffocated or crushed by the animals that are placed above them. Both these factors together with the aversiveness of pigs to CO_2 strongly support the use of alternative methods of on-farm killing by producers who are concerned for the welfare of their livestock.

Physical Methods

Blunt force trauma (manual): On-farm killing of young pigs was traditionally carried out by administering a blow to the head, which was generally performed by swinging the young animal against the floor or a wall. The impact of the animals' head against a solid surface equates to the same principle as mechanical stunning, however its effectiveness as an on-farm killing method is highly dependent on the skill of the stockperson. It is also a method of killing that is aesthetically unpleasant for both the operator and any bystanders. The Humane Slaughter Association carried out a survey in the UK in 1993 to look at the culling methods used for livestock on-farm. The results showed that at that time, the majority of piglets were usually killed by a blow to the head. The majority of respondents were not satisfied with their current method of on-farm killing and all of them expressed an interest in an alternative device.

A non-mechanical (manual) percussive blow to the head is not considered to be an acceptable routine stunning method for any species (at any age). The AVMA (2013) encourages those using manually applied blunt force trauma to the head as a euthanasia method to actively search for alternatives to ensure that criteria for euthanasia can be consistently met.

Non-penetrating captive bolt:
Mechanical stunning employs a percussive blow to the skull to produce brain dysfunction through the induction of a concussed state. The stun can be recoverable e.g. as in a boxer's 'knock-out blow', or irrecoverable if extensive physical damage to brain tissue is produced in the case of a stun/kill. With mechanical stun/killing it is difficult to calculate exactly the forces acting on the head. However, the energy of the mechanical stunning system can be measured.

Kinetic Energy (Joules) = $0.5 \times mv^2$

where, m = mass (bolt weight) and v = bolt velocity

The relationship between Velocity, Mass and the resulting Energy produced is such that a change in the weight of the bolt produces a very small change in the energy of the mechanical system compared to changing the velocity of the bolt therefore, maintaining the velocity of the bolt is critical to ensure an effective stun. Research by Casey-Trott, et al., (2014) demonstrated that piglets (3-9 kg) were humanely stun/killed by the Zephyr-E when applied twice on the frontal bone. Subsequently the Zephyr-EXL was developed by Bock Industries to produce sufficient energy to ensure that a single shot would result in sufficient physical trauma to the brain to both stun and prevent recovery, producing an immediate stun/kill (Grist, et al., 2017).

Research (Grist, et al., 2017) has demonstrated that it is important when shooting piglets to support the head of the piglet on a hard surface for maximum energy transfer to the animal to ensure an effective stun/kill. The energy requirement, for an effective stun/kill with piglets, is greater or equal to 27.7 Joules. The energy developed by individual devices can be determined from the manufacturer's website (Bock Industries). Whiting, et al., (2011) concluded that for the mass killing of healthy, surplus piglets and considering animal welfare objectives in isolation, non-penetrating captive bolt was superior to all other techniques attempted. The methods tested were manual blunt force trauma, controlled blunt force trauma, intra-peritoneal injection of barbiturate, and free bullet.

Post-shot movement is an expected result of an effective stun-kill. The important organ when assessing the death of an animal is the brain. Following an effective percussive blow the brain is no longer functioning. However, death is a process that starts with the higher centres of the brain followed by other parts of the animal, for example the spinal cord, which will die more slowly. Once the brain is dead, spinal reflexes are released from the control exerted by the brain and post-shot movement will result. These will gradually subside. Some piglets will bleed from the nose due to the force of the blow – this is not a welfare concern, as the brain of the animal is no longer functioning.

Assessment of the effectiveness of the shot: Following the shot the piglet should be assessed as follows:

- the piglet should not be breathing rhythmically
- there should be no corneal reflex (a blink in response to touching the eye), and
- the absence of a response to a painful stimulus (a nose prick with needle)

The abolition of these responses indicates an effective stun-kill.

Gasping respiration, or agonal breathing, may be present in a small number of piglets. In the dying animal, this is the last respiratory pattern prior to loss of movement and is not a welfare concern (Grist, et al., 2017).

Shooting position: The shooting position for piglets is on the midline between the eyes and the ears on the frontal/parietal bone.

Free-bullet:

Firearms with a free projectile (free bullet) of appropriate charge or calibre (shotguns, rifles, pistols) are also commonly used methods for killing larger pigs on-farm (HSA, 2016). Handguns are ideal for shooting at close range (less than 10 cm), shotguns at a distance between 5 and 25 cm, and rifles for long distance (few meters) shooting (Longair, et al., 1991). Their use with piglets must be treated with care due to their thin skull structure and the potential for free-bullets to pass through the head of the animal producing little structural damage. Operator health and safety issues must be highlighted. When used properly, a free bullet provides a quick and effective method of killing as it requires minimal or no restraint and can be used to kill from a distance. With a successful shot, death is immediate and there is no requirement for further bleeding or pithing of the animal. Effective killing with a free bullet produces the following outwardly signs (HSA, 2016):

- Animal collapses immediately after the shot and stops breathing.
- Carcass can be 'tonic' or relaxed.

- Eyes have a fixed and glazed expression.
- No corneal reflex.
- Convulsions may occur after a lapse of up to 1 min.
- Pigs go very fast (<5 sec) into severe clonic convulsions with uncoordinated kicking and paddling movements of the legs.
- Death is confirmed by the absence of breathing, pupillary and corneal reflexes.

This method should only be attempted by individuals trained in the use of firearms (EFSA, 2004).

POULTRY

Lethal Injection: Barbiturates are normally used as anaesthetics, but are also effective in producing euthanasia when given as an overdose. In general, three times the anaesthetic dose causes death quickly (AVMA, 2000). It is generally used at a dosage of 200 mg/kg body weight or, 1ml (200 mg/ml) per 1.4 kg in birds is the recommended dose for euthanasia by intravenous route. The action of the barbiturates is to depress the central nervous system, causing anaesthesia. When administered as an overdose, the anaesthesia is followed by depression of the respiratory centre, apnoea, cardiac arrest and death. Sodium pentobarbital is the most suitable barbiturate for euthanasia of birds and intravenous administration is preferred because the effect is the most rapid and reliable.

Inhaled Agents: Any gas that is inhaled must reach a certain concentration in the alveoli before it can be effective; therefore, euthanasia with any of these agents takes some time. The suitability of a particular agent depends on whether an animal experiences distress between the time it begins to inhale the agent and the time it loses consciousness (AVMA, 2007). The use of CO_2 at high concentrations with poultry has been shown to be aversive (McKeegan, et al., 2006; Sandilands, et al., 2011; Raj, et al., 2006). Exposure of birds to anoxia results in a less aversive induction of unconsciousness but it is more difficult to control practically and there are aesthetic and welfare concerns.

Exposure of poultry to gas mixtures in particular anoxic gas mixtures, results in convulsions manifested as wing flapping, which could be aesthetically unpleasant to some people and some others may describe it as a violent death (Coenen, et al., 2000). The time to onset and severity of convulsions seem to vary according to the rate of induction of unconsciousness with the gas mixture and the CO_2 concentration in the atmosphere. For example, Raj and Gregory (1990) reported that the time to onset of convulsions in broilers was significantly shorter when a target concentration of 45% CO_2 in air was created in the stunning chamber in 8 seconds when compared with 18 seconds (29 and 38 seconds to the onset of convulsions respectively). Research has shown that residual oxygen of 2% in argon or nitrogen is essential to rapidly induce unconsciousness and death in poultry. It has been reported that exposure of broilers to 2% residual oxygen in argon resulted in loss of posture on average at 11 seconds and onset of convulsions at 22 seconds (Raj et al., 1991). The research implications suggest that the onset of anoxic convulsions themselves can be used as an indicator of the loss of consciousness. Therefore, it is reasonable to assume that the convulsions themselves do not have any bird welfare implications. However, Webster and Fletcher (2004) expressed concern that the variation in time to loss of posture would result in some birds being conscious while others convulsing in an unconscious state. Under this situation, the experience of seeing other birds convulse and of being struck by bodies and flapping wings might have negative impact on the welfare of poultry, however for a short duration.

When larger numbers of birds are required to be killed on-farm, gas killing, via portable small-scale containerised equipment brought onto the farm for that purpose and using permitted gas mixtures at specific concentrations, is currently an acceptable method. The progressive exposure to CO_2 concentrations observed in some gas systems appears to reduce aversive responses amongst poultry. The birds do not react vigorously to the lower concentrations of gas through wing flapping and there was little evidence of wing flapping in with progressive exposure. In addition, nitrogen-filled foam has been proposed by Raj et al., (2008) and McKeegan et al., (2013) demonstrated that nitrogen-filled foam delivered a reliable and humane kill through anoxia. However, both these systems are not practical for small numbers of birds, on-farm.

Physical Methods:

Cervical Dislocation: The most common method for the on-farm killing of all farmed species of poultry has been neck/cervical dislocation. Cervical dislocation kills through a rupturing of the spinal cord and/or damage to major blood vessels in the neck causing the cessation of breathing and loss of oxygenation to the brain. There is significant evidence that manual cervical dislocation does not produce immediate loss of consciousness (Gregory and Wotton, 1990a; Erasmus et al., 2010; Sparrey et al., 2014). Gregory and Wotton (1990a) showed that, only 3 of 8 birds showed signs of concussion when the necks were dislocated by stretching, and only 1 of 16 birds when the necks were dislocated by crushing, suggesting that both methods of cervical dislocation may not induce immediate loss of consciousness. They concluded that cervical dislocation should be ideally performed in unconscious poultry.

Various tools have been developed for killing poultry through cervical dislocation on-farm, e.g. crushing methods such as burdizzos or pliers (Sparrey, et al., 2014) but there is no neurophysiological evidence that these methods produce immediate loss of consciousness and they are no longer permitted under current European legislation (Council Regulation (EC) No 1099/2009). Since Council Regulation (EC) 1099/2009 came into force on 1 January 2013, manual cervical dislocation can only be used for birds under 3kg live weight and no more than 70 birds can be killed in this manner per handler per day. Therefore, pressure is being applied through legislation to develop a more humane alternative to cervical dislocation.

Decapitation: Decapitation is another method of killing poultry that has been shown to have serious welfare implications. Gregory and Wotton (1986) investigated the time to loss of spontaneous EEG activity following decapitation, and various commercially-practiced neck cutting procedures. In that study, the time to reach 5% of the pre-slaughter integrated EEG activity (32 s following decapitation) was used as one of the criteria to determine the state of brain function in chickens. The time was suggested to be an overestimate because of the effects of anaesthetic used and mechanical ventilation provided to birds. Nevertheless, decapitation did not result in immediate loss of consciousness and is no longer supported as a back-up method of killing birds that miss the stunner and/or the neck cutter in commercial processing plants (Council Regulation (EC) No 1099/2009). Another disadvantage is the spillage of blood produced by decapitation, which is worsened by severe wing flapping EFSA, 2004).

Blunt force trauma (manual): UK legislation (WATOK, 2015) is clear that *"No person may stun an animal using a non-mechanical percussive blow to the head"* (except for rabbits). A manual percussive blow to the head might be applied by a hand-held object but requires ability and confidence to be achieved swiftly, consistently, accurately and effectively. This is unlikely to be found on all farms. FAWC (2017) considers it should only be used in emergency circumstances when there is no other method available. The problem with manual blunt force trauma is ensuring that sufficient impact velocity is produced with every application. In addition, movement of the bird's head during the application can result in miss-hits with consequences for bird welfare. As described above for piglets, a non-mechanical (manual) percussive blow to the head is not considered to be an acceptable routine stunning method for any species (at any age). The AVMA (2013) encourages those using manually applied blunt force trauma to the head as a euthanasia method to actively search for alternatives to ensure that criteria for euthanasia can be consistently met.

Non-penetrating captive bolt: Mechanical blunt force trauma is an alternative method that delivers a more controlled percussive blow to the head that results in an immediate stun/kill. Non-penetrating captive bolt relies on the kinetic energy delivered to the cranium to produce concussive effects within the brain, based on the velocity of the impact rather than the mass of the object (Daly, et al., 1987). The concussion produced by this impact is often associated with both haemorrhaging at the impact site ('coup') and further haemorrhaging opposite the impact site ('contra-coup') (Ommaya, et al., 1971).

Research at Bristol University (Hewitt, 2000) described the development of a non-penetrating captive bolt for the humane destruction of poultry (chickens and turkeys). In a subsequent Government funded project the use of a non-penetrating captive bolt was evaluated with ducks and geese (DEFRA, 2005). These research projects applied a neurophysiological approach to the assessment of brain function following the application of a non-penetrating captive bolt using the abolition of Visual Evoked Potentials in the EEG to demonstrate the immediate loss of residual consciousness and brain death in poultry. Further research by Erasmus, et al. (2010) demonstrated that a non-penetrative captive-bolt device consistently induced insensibility in turkeys leading to death, whereas all birds showed signs of sensibility after manual and mechanical cervical dislocation. Therefore, these results demonstrate that a non-penetrating captive bolt, that delivers ≥27 Joules, will produce a humane stun/kill in all species of poultry. The research also demonstrated that a flat percussive head was suitable for chickens but a convex head was necessary for turkeys, ducks and geese. The convex shaped head enables energy transfer through the loose skin of the head of larger species of poultry, to the skull resulting in an effective stun/kill.

Electrical Stun/kill: Electrical head-only stunning followed by a killing method e.g. electrically induced ventricular fibrillation or, cervical/neck dislocation, is a recognized method for the humane killing of poultry on-farm. Hand-held or portable electrical stunners can be used however, any electrical stun must span the brain (FAWC, 2017) and head-only stunning results in a temporary period of unconsciousness following which the bird will recover therefore, the killing method must be performed quickly. Head-only electrical stunning is normally performed on poultry that are restrained in a cone or shackle and both can be distressing to birds due to inversion (EFSA, 2004). When electrical currents are applied head-only to poultry the passage of the current through the brain will result in immediate unconsciousness. Because the brain is no longer controlling spinal reflexes, the birds will flap vigorously therefore, stunning current should be applied for a minimum of 7 s or until the wing flapping stops (Gregory and Wotton, 1990b and 1991).

There are various tools on the market to deliver an electrical stun/kill for example, electric stunning knives (e.g. Knase Company Inc.). These applicators have a single point contact with the circuit being completed through a shackle that must be earthed. There is a potential for the current pathway to bypass the brain and when sufficient current is applied to both stun and kill poultry, there is a health and safety risk to the operator.

Minimum currents for effective head-only electrical stunning of poultry are: 240 mA for chicken; 400 mA for turkeys (Council Regulation (EC) No 1099/2009); 600mA for ducks (Beyssen, 2004). However, research has demonstrated that head-only electrical stunning is not effective with geese up to currents >1 Amp (Fernandez, 2010), which would exceed current health and safety requirements.

Free-bullet: Gunshot is not recommended for poultry where restraint and an alternative method is feasible.

Conclusion: It is recommended that all livestock farms should have ready access to suitable equipment for the humane killing of all farmed animal species, sizes and ages kept on the premises and that all equipment kept on farm for the killing of animals must be maintained in good working order, cleaned after use and stored in suitable facilities as per manufacturer's instructions. The exposure of pigs and poultry to CO_2 on-farm should be avoided where other more humane methods of despatch are available. The Zephyr-EXL and the TED (Bock Industries) meets this recommendation for neonate swine and all poultry species.

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