Wednesday 15th May 2024

Pig Stunning Methods

Introduction

- The slaughter process for farm animals in the UK has two main stages – stunning followed by sticking.
    - Stunning is any intentionally induced process that causes loss of consciousness and loss of sensibility without pain.
    - Sticking is the process whereby the animal's neck is cut to ensure rapid blood loss and therefore death[1] whilst remaining 'stunned' and insensible to pain.
- In pigs, there are three main methods available for stunning[1]:
    - **Captive bolt** (using a captive bolt pistol)
        - Pigs are some of the most difficult animals to stun by this method as their brain is small, lies deep within the skull and behind a thick frontal bone[2].
        - This method is often reserved as a backup method in the abattoirs, or used in small-scale abattoirs or for on-farm slaughter and will not be discussed further in this briefing.
    - **Electrical stunning**:
        - This can consist of a head-only stun, a cardiac stun, or a combination of both.
        - Depending on the method used, the animal is either stunned (head-only) or killed (cardiac and combination)[3].
    - **Controlled Atmospheric Stunning (CAS)**:
        - Commonly high concentration carbon dioxide (CO_2) is used, but alternatives include inert gas mixes, including nitrogen and argon.
- In 2022, 88% of UK pigs were stunned with high concentration CO_2, with almost all the remaining 12% stunned via electronarcosis to the head, a proportion that has undergone very little change since the 4 years prior[4].
- **Minimising welfare issues before stunning:**
    - Pigs have poor eyesight but good hearing, and therefore avoiding loud sounds, sudden movements or darkness, and shadows can reduce complications when moving pigs from the lairage to the stunning facilities[3].
    - Furthermore, pigs naturally stay in groups and will avoid passages whereby they are channelled single file.
        - This is more common when using individual stunning methods i.e. electrical or captive bolt stunning, compared to gas stunning where pigs can be kept in small groups.
        - In instances of individual stunning, excessive force may be used to get the pigs to move along the system, which causes distress and affects pig welfare prior to slaughter as well as the quality of the carcass.

What constitutes an effective stun?

- Correct and effective stunning is essential to ensure the animal remains unconscious before death by blood loss occurs[5]. This requires the correct positioning of tongs and correct currents (in instances of electrical stunning) and the correct cartridge (used in captive bolt stunning) must be used[5].
- Effective stuns **must** cause loss of consciousness, loss of pain, and immobility.
- The European Commission released guidance that suggested stunning to render the animal unconscious and sticking within 15 seconds to ensure a painless death, is vital to optimise welfare[3].

[1] https://www.rspca.org.uk/adviceandwelfare/farm/slaughter/factfile
[2] https://www.hsa.org.uk/positioning/pigs
[3] https://food.ec.europa.eu/document/download/f80a4025-3faa-460c-8a54-53a65207575f_en?filename=aw_prac_slaughter_factsheet-2018_farm_pigs_en.pdf
[4] https://assets.publishing.service.gov.uk/media/62f0eec1d3bf7f75b305fbae/Results-of-the-2022-FSA-Slaughter-Sector-Survey-in-England-and-Wales.pdf
[5] https://www.rspca.org.uk/adviceandwelfare/farm/slaughter/keyissues

Gaseous Stunning Techniques:

- **High Concentration Carbon Dioxide:**
  - **Production of a Stun:**
    - Pigs are moved in small groups into stunning chambers which are lowered into high concentration CO_2 (HCC) gas, usually over 90%[6].
    - Inhalation of HCC rapidly increases blood CO_2 levels (hypercapnia) leading to respiratory acidosis, which quickly reduces intracellular pH throughout the pig's central nervous system[7] and results in unconsciousness.
      - They exact mechanism for the unconsciousness may be a combination of the destruction of brain neurones, alteration of action potential formation, and lower blood O_2 concentrations resulting in cerebral ischaemia[8].
      - Due to spinal cord necrosis, the animal does not undergo convulsions, which prevents damage to the carcass and other carcasses in the same system.
    - Pigs are rendered unconscious after approximately 30-60 seconds[9], however pigs are kept in chambers for up to 3 minutes to ensure complete loss of consciousness[7] and eventual death by hypoxia[32].
  - **CO_2 Specific Advantages:**
    - Meat quality tends to be better compared to when electrical stunning is used, although there is variation within and between each system[10].
      - This can either be attributed to the lower stress pre-stunning (animals are in groups), or the stunning method itself.
    - CO_2 is cheaper and more accessible than alternative gases[11].
    - CO_2 is denser compared to other gases and therefore can be contained easily[12].
    - The CO_2 used can be repurposed as a by-product of fertiliser production[13].
  - **CO_2 Specific Disadvantages:**
    - HCC stunning has been shown to be aversive in pigs, causing pain, fear, and distress before a loss of consciousness develops[14]:
      - CO_2 stunning is associated with vigorous movements and behaviours which may, or may not, be conscious reactions[15].
      - Inhalation of CO_2 concentrations >30% has been shown to cause aversion in pigs[16].
        - Pigs will avoid and attempt to escape high CO_2 environments and have increased vocalisations when within the high CO_2 environment[31].
        - A study measured changes in spontaneous electro-corticogram and somatosensory evoked potentials (SEPs) caused by the low pH effect of HCC stunning in 12 pigs. They found that the acidic conditions produced by CO_2 caused severe irritation of the eye, nasal mucosa, and the lungs[17].

[6] https://kb.rspca.org.au/knowledge-base/what-are-the-animal-welfare-issues-associated-with-different-stunning-methods-for-pigs-at-slaughter/#ftn1
[7] Hognestad BW, Digranes N, Opsund VG, Espenes A, Haga HA. CO_2 Stunning in Pigs: Physiological Deviations at Onset of Excitatory Behaviour. Animals (Basel). 2023 Jul 23;13(14):2387. doi: 10.3390/ani13142387. PMID: 37508164; PMCID: PMC10376161.
[8] C. Terlouw, *et al*. Consciousness, unconsciousness and death in the context of slaughter. Part I. Neurobiological mechanisms underlying stunning and killing, Meat Science, Volume 118, 2016, Pages 133-146, ISSN 0309-1740, https://doi.org/10.1016/j.meatsci.2016.03.011.
[9] https://www.eurogroupforanimals.org/files/eurogroupforanimals/2022-03/CO2%20stunning%20EfA%20position%20paper%202019.pdf
[10] Jongman, Ellen. (2022). Electrical versus CO2 stunning of pigs: effects on animal welfare and meat quality. 10.1016/B978-0-323-85125-1.00091-0.
[11] https://www.eurogroupforanimals.org/files/eurogroupforanimals/2022-03/CO2%20stunning%20EfA%20position%20paper%202019.pdf
[12] https://www.embrapa.br/documents/1355242/0/Seminário+boas+práticas+-+Gas+stunning+of+pigs.pdf
[13] https://www.bbc.com/news/business-58600583
[14] E. Sindhøj, *et al.* Review: Potential alternatives to high-concentration carbon dioxide stunning of pigs at slaughter, Animal, Volume 15, Issue 3, 2021, 100164, ISSN 1751-7311, https://doi.org/10.1016/j.animal.2020.100164.
[15] Hognestad BW, Digranes N, Opsund VG, Espenes A, Haga HA. CO_2 Stunning in Pigs: Physiological Deviations at Onset of Excitatory Behaviour. Animals (Basel). 2023 Jul 23;13(14):2387. doi: 10.3390/ani13142387. PMID: 37508164; PMCID: PMC10376161.
[16] https://www.ufaw.org.uk/downloads/awj-abstracts/v21-1-llonch.pdf
[17] B.M. Raj, *et al.* Welfare implications of gas stunning pigs: 3. the time toloss of somatosensory evoked potential and spontaneous electrocorticogram of pigs during exposure to gases, The Veterinary Journal, Volume 153, Issue 3, 1997, Pages 329-339, ISSN 1090-0233, https://doi.org/10.1016/S1090-0233(97)80067-6.

        - Inhalation of HCC induces respiratory distress, resulting in a feeling of breathlessness and causes the pig to gasp or intensely breathe, which may be distressing for the animal[12].
        - Furthermore, this discomfort may differ between sows and pigs, making the assessment of the impact more difficult[18].
    - There may be increased risk of lumbar muscle haemorrhages compared to other stunning methods[11].
    - There have been recent reports of disruption to CO_2 supply[13].
- **Argon and CO_2 mixtures:**
    - **Production of a Stun:**
        - A stun using argon is typically made up of 90% argon in air or a 30% CO_2 and 70% argon mix. Oxygen concentration is removed to <2% at which point there is not enough oxygen to support brain function, and the animal dies.
        - A stun is induced through hypoxia/anoxia[12], which eventually causes death.
    - **Argon Specific Advantages:**
        - The mean time to loss of SEPs has been shown to be significantly lower with argon and argon-CO_2 mixtures, compared to HCC mixtures[17].
        - Welfare is superior compared to CO_2 in the induction phase. Aversion in pigs is lower with argon, and argon-CO_2 mixtures than with pure CO_2. However, aversion is more with argon-CO_2 mixtures, compared to 90% argon mixes[19].
        - Argon is a non-flammable, non-explosive, inert, and readily available gas[20]. It is denser than air and therefore can be stored readily[12].
    - **Argon Specific Disadvantages:**
        - Argon-mix stunning has a longer time to loss of posture compared to CO_2 and N_2/CO_2 gas mixture stunning[19].
        - Argon is more expensive than CO_2, preventing its commercial usage[32], and the economic return due to improvements in carcass meat quality is relative[12].
        - Gas exposure times are long, often >7 minutes, as early removal results in rapid regaining of conciousness[12].
        - Poorer carcass quality:
            - Anoxia can have links to pale-soft-exudative (PSE) meat, which results in poor carcass quality[12] and lowers the value of the derived meat.
            - Furthermore, many pigs undergo anoxic convulsions as there is no effect of the gas on the spinal cord, which leads to carcass damage.
- **Variations:**
    - Recent studies include mixes of another inert gas, nitrogen (N_2). However, there is evidence that there is more aversion to N_2 and CO_2 mixtures, compared to 90% argon mixtures[20].
    - A novel technique using nitrogen gas foam in a closed container suggests a reduced aversion when compared to the use of pure nitrogen gas, however the research surrounding this technique is limited[12].
- **General Advantages and Disadvantages of Gaseous Stunning in Pigs[12]:**
    - **Advantages:**
        - Can be used in group stunning scenarios[14]:
            - Reduces human restraint required which could reduce stress immediately prior to the stunning process.
            - Beneficial in large, high throughput abattoirs.

[18] I.Lechner, *et al.* Discomfort period of fattening pigs and sows stunned with CO2: Duration and potential influencing factors in a commercial setting, Meat Science, Volume 179, 2021, 108535, ISSN 0309-1740, https://doi.org/10.1016/j.meatsci.2021.108535.
[19] Dalmau A, Rodríguez P, Llonch P, Velarde A. Stunning pigs with different gas mixtures: aversion in pigs. *Animal Welfare*. 2010;19(3):325-333. doi:10.1017/S096272860000172X
[20] https://www.avma.org/sites/default/files/2020-02/Guidelines-on-Euthanasia-2020.pdf

- Due to the automated gas concentration system, there is less risk of human error compared to electrical stunning meaning a stun is more likely to be effective, with a reduced chance of the animal regaining consciousness[12].
- Produces relaxed carcases which improve operator safety[12].

- **Disadvantages:**
  - There have been occasions where the availability of the gas supply has been interrupted[12].

Electrical Stunning Methods

- **Methods:**
  - **Head-only stunning:**
    - Electric tongs are placed on the upper neck, between the eyes and the base of the ears.
      - It is vital that tongs are in the correct position to ensure an effective stun.
      - A minimum 1.25amps must be passed through a pig's brain to reliably produce an effective stun[21], with larger pigs often requiring a higher amperage.
        - Insufficient amperage, or a current path that fails to go through the brain will be perceived as pain by the animal[21].
    - Applying an electric current to the tongs for at least 1-3 seconds creates a **reversible** stun by **inducing a generalised seizure** whereby the animal becomes immediately unconscious and unable to feel pain[21].
      - Failure to produce a seizure could cause the animal to become paralysed but remain sensible to pain[21].
    - If an epileptic seizure has been generated, then the animal will exhibit a tonic and a clonic phase[21].
      - The **tonic phase** causes the immediate collapse of the animal, and it enters a rigid phase.
        - The forelimbs and hindlimbs are stretched forward, breathing is absent and the eyeballs are in a fixed position or rotated into the socket[22].
        - Sticking is ideally performed in this phase[22].
      - The **clonic phase** consists of excessive kicking or paddling movements.
    - Pigs should be bled within 30 seconds, although a shorter interval of 10-17 seconds is recommended[21].
  - **Cardiac-only stunning:**
    - An electrode is placed on the head (forehead, or hollow behind the ears) and the second electrode is placed on the back or the side of the pig.
    - Applying an electrical current for 2-3 seconds **induces a cardiac arrest** and **kills** the pig[21].
      - High frequencies will render the animal unconscious, but they will not induce a cardiac arrest[21].
    - This method requires a restraining device to ensure the full stun is given to the pig and is commonly found in large pig units[21].
    - The benefits include creating a still carcass that is easier to bleed.[21]
  - **Combination of head and cardiac stunning:**
    - This uses a combination of head and cardiac stunning and was developed due to the reduced effectiveness in producing an adequate stun through head-only stunning[21].
    - The cardiac stun can either be in combination with the head stun, or immediately afterwards to generate a cardiac arrest and kill the animal.

[21] https://www.fsis.usda.gov/sites/default/files/media_file/2021-07/2015-Electric-Stunning-of-Pigs-and-Sheep-Temple-Grandin.pdf
[22] https://efsa.onlinelibrary.wiley.com/doi/10.2903/j.efsa.2020.6148

- When applied together the signs of an effective seizure are difficult to observe[21].

- **Advantages:**
  - Modern facilities use a constant amperage regulated design system i.e., the amperage is fixed, and the voltage varies depending on the animal. This helps ensure that the amperage will be adequate to induce an epileptic seizure or a cardiac arrest[21].
  - Electrical stunning produces a good effective stun if used correctly:
    - Correct placement of electrodes is essential.
    - Correct amperage is essential.
    - Regularly serviced and well-maintained machines are essential.
  - During the actual stunning process, there is less suffering compared to HAC systems[32].
- **Disadvantages:**
  - Dehydrated animals are more difficult to effectively stun.[21]
  - Electrical stunning requires skilled personnel to ensure:
    - Correct electrode placement and exposure time[22] and therefore induction of an epileptic seizure or cardiac arrest.
      - In a 2004 study, it was found that in the UK 15.6% of pigs were incorrectly stunned with head-only electrical stunning methods[23].
    - Current is only administered to the electrodes once it has been applied to the body of the animal[21].
      - This prevents pre-stun shocks which increase the likelihood of blood splash in the carcass from muscles which have been tensed more than once[22], reducing the meat quality.
    - If automatic placement of electrodes is used, or inadequate restraint, pre-stun shocks or an ineffective stun can ensue with deleterious implications for meat quality and animal welfare[24].
  - Pigs naturally move in groups, and therefore moving pigs into the restraint necessary for electrical stunning of any kind goes against this natural behaviour[25].
    - Pigs that are jammed in the race (between lairage and stunning facilities) or are goaded with electrical probes are more stressed prior to slaughter[23], which increases lactate production in muscles and results in poorer carcass quality.[21]
  - Electrical stunning produces intense muscle contractions. This can lead to broken bones (often vertebrae or shoulders) and blood splash in the muscles. Carcass damage accelerates the rate of post-mortem pH reduction in the tissues and contributes to PSE condition which reduces carcass quality[26].
    - Higher frequencies reduce meat damage (prevent blood splash and broken bones), but frequencies >800Hz are frequently ineffective at inducing seizures and generate a shorter period of insensibility[21].
  - Regarding head-only stunning, the short time between stunning and the animal returning to insensibility may be difficult to achieve in smaller plants[21].
    - A 2011 study showed that the combination of head and cardiac stunning is an effective alternative to head-only electrical stunning to prevent the risk of pigs regaining consciousness during the bleeding process if there is any delay after stunning[27].

[23] J.L. McKinstry, M.H. Anil, The effect of repeat application of electrical stunning on the welfare of pigs, Meat Science, Volume 67, Issue 1, 2004, Pages 121-128, ISSN 0309-1740, https://doi.org/10.1016/j.meatsci.2003.10.002.
[24] Velarde A, Gispert M, Faucitano L, Manteca X, Diestre A (2000) Survey of the effectiveness of stunning procedures used in Spanish pig abattoirs. Veterinary Record 146(3):65–8
[25] Von Wenzlawowicz M, Von Holleben K, Eser E (2023) Identifying reasons for stun failures in slaughterhouses for cattle and pigs: A field study. Animal Welfare 21(S2):51–60
[26] https://porkgateway.org/resource/electrical-stunning-of-pigs-using-high-frequency-electrical-currents/)
[27] Vogel KD, Badtram G, Claus JR, Grandin T, Turpin S, Weyker RE, Voogd E (2011) Head-only followed by cardiac arrest electrical stunning is an effective alternative to head-only electrical stunning in pigs. Journal of Animal Science 89(5):1412–8

Other Stunning Methods

- **Low Atmospheric Pressure Stunning (LAP):**
  - This stunning technique is being investigated as a potential humane alternative stunning method due to shortfalls in animal welfare and carcass quality in the most commonly used pig stunning systems – HCC or electrical.
    - Current research is in its infancy, however relevant research from investigations into low pressure physiology in humans, hypoxia used in pig euthanasia, and the use of LAPS for stunning poultry may allow for extrapolation to discern the effectiveness and viability of this method in pigs[28].
  - **Production of a Stun:**
    - Progressive decompression is applied to a group of animals in a sealed container. This results in unconsciousness, from low pressure (hypobaric), followed by death by hypoxia.[29]
    - A study conducted in 2022 on 60 10-week-old, anaesthetised piglets characterised decompression rates for LAPS in pigs[30]. They found:
      - Faster decompression rates resulted in shorter times to cardiac arrest and cessation of breathing, however a higher incidence of pain from barotrauma was noted in a different study[32].
      - Slower decompression rates were associated with repeated prolonged whole-body movements, which likely reduce carcass quality.
      - However, the study provided no information on the welfare outcomes associated with decompression in pigs, which needs to be explored before assessing viability of this stunning method.
  - **Advantages:**
    - In poultry, LAPS produces a consistent stun and removes the need for shackling and handling which is stressful. It has been suggested that these advantages would also be present in pigs stunned via this method.[29]
    - Pigs can be stunned and killed in groups[31].
  - **Disadvantages:**
    - There is concern that rapid decompression could cause expanded gas to become trapped in body cavities, risking the quality of the meat and possibly causing discomfort to the animal[29]. This is less common in poultry (due to anatomical differences in the bird gastrointestinal system) but could be more of an issue in mammals.[29]
    - There is considerable debate whether this is a humane alternative for pig stunning.
      - Recent research finds that using LAPs in pigs suffering from upper respiratory tract disease, have excess stomach gas, or tooth decay might experience pain from this method of stunning.[28]
      - Furthermore, another paper founds that pigs are likely to experience some level of ear pain and air hunger before they lose consciousness[29,31].
      - Another study found aversive behaviour was experienced with LAPS, as well as higher counts of head shaking, low head carriage and facial grimace[31].
      - Co-founded research between the Humane Slaughter Association (HSA) and the UK Department for Environment, Food and Rural Affairs (DEFRA) found

[28] Bouwsema J, Lines J. Could low atmospheric pressure stunning (LAPS) be suitable for pig slaughter? A review of available information. *Animal Welfare*. 2019;28(4):421-432. doi:10.7120/09627286.28.4.421
[29] https://kb.rspca.org.au/knowledge-base/what-is-low-atmospheric-pressure-stunning-laps/
[30] Martin Jessica E., Baxter Emma M., Clarkson Jasmine M., Farish Marianne, Clutton Richard E., Greenhalgh Stephen N., Gregson Rachael, McKeegan Dorothy E. F., Characterizing candidate decompression rates for hypobaric hypoxic stunning of pigs. Part 1: Reflexive behavior and physiological responses, Frontiers in Veterinary Science, Vol 9, 2022, https://www.frontiersin.org/articles/10.3389/fvets.2022.1027878, DOI 10.3389/fvets.2022.1027878, ISSN 2297-1769
[31] Martin, Jessica & Baxter, Emma & McKeegan, Dorothy. (2020). Low atmospheric pressure stunning in poultry and pigs – does LAPS offer a solution to an emotive subject?.

that LAPS is **not** a humane alternative for stunning pigs, despite its humane associations in stunning poultry prior to slaughter[32].
    - However other sources suggest that healthy, fasted pigs were unlikely to feel the adverse effects of LAPs[28].
- The total killing cycle in pigs would likely take 9-14 minutes.[28]
    - There is a longer time to loss of consciousness in LAP stunning compared to CO_2.[31]
    - Slow decompression rates extend the period to loss of consciousness, with welfare implications[31,32].
- Multiple decompressions cylinders would be necessary for commercial implementation28, which would likely be expensive.

Conclusion

- There is no perfect stunning method currently in use for the commercial slaughter of pigs in the UK.
- It is almost unanimously agreed by numerous industry stakeholders that an alternative, humane stunning method needs to be developed for widespread commercial use.
    - In 2003, the Farm Animal Welfare Council (FAWC) recommended that the gas used to induce unconsciousness for stunning should not be aversive[33], and concludes that the use of HCC to stun and kill pigs is unacceptable, and is a practice they '*wish to see phased out in 5 years'*[34], yet over two decades later, this method continues to be widely used.
    - Similarly, the HSA recommends that despite the advantages of HCC stunning systems (reduced pre-stun stress and automation), they do not negate the negative welfare impacts of HCC stunning, and therefore an alternative, more humane method for pig stunning needs to be developed as a matter of urgency[32].

Recommendations

- For a new stunning system to be practicable, it must be an economically feasible alternative, have limited negative implications on animal welfare, not compromise meat quality and have little impact on abattoir throughput[32].
    - Despite alternatives to HCC stunning in the UK likely being expensive and timely to implement, the 2003 FAWC Report states that it '*does not see the achievement of engineering solutions as an insurmountable problem'* when it comes to altering pig stunning methods in the UK[34].
    - The ideal stunning system would allow group stunning and non-aversive to maintain animal welfare prior to and during the stunning process, as well as optimise carcass quality as much as possible.
- Electrical Alternatives:
    - Some stakeholders believe that electrical stunning is the only real alternative to HCC stunning in pigs.
        - Eyes on Animals, an animal welfare charity, in combination with animal welfare experts, renovated a Dutch abattoir with a throughput of 600 pigs a day by installing 4 automated electrical stunners[34]. They started the project to improve automatic stunning facilities, so they become 'an appealing alternative to CO_2 stunning both in terms of animal welfare and economically.'[35]
        - **The superiority of electrical stunning** compared to HCC stunning **relies on well-trained stockmen** and **well-maintained equipment.**
    - Others argue that CO_2 stunning is a better alternative compared to poorly done electrical stunning[12]. This is due to welfare concerns around individual pig isolation, stress of restraint,

[32] https://sciencesearch.defra.gov.uk/ProjectDetails?ProjectId=19805
[33] https://assets.publishing.service.gov.uk/media/5a7ed35f40f0b62305b836b2/FAWC_report_on_the_welfare_of_farmed_animals_at_slaughter_or_killing_part_one_red_meat_animals.pdf
[34] https://bvajournals.onlinelibrary.wiley.com/doi/10.1002/vetr.4093
[35] https://www.eyesonanimals.com/vet-record-journal-publishes-articles-about-eonas-improvements-to-electric-stunning-so-that-abattoirs-can-move-away-from-co2-gas/

poorly maintained stunning devices, high rates of ineffective stunning, and the risk of recovery to consciousness (head-only stunning)[12].

- If there was a way of electrical stunning to be carried out in groups and result in the cardiac arrest and therefore death of the pig, this would maximise animal welfare prior to stunning and improve carcass quality compared to seizure-induced electrical stunning techniques.
  - One such method might be exploring the use of a ground level electrocution circuit whereby a current can be applied to a conductive surface where groups of pigs are standing, induce a cardiac arrest and kill the animals in unison.

- Alternative Gas Systems:
  - Inert Gas Systems:
    - There is ongoing research into the practicability of retrofitting inert-gas units into existing CO_2 units. However, there is concern regarding the cost of facility conversion, as well as increased maintenance costs when using the more expensive inert gas mixtures.
    - A system that recycled the gas used in the stunning process, would help improve the economic viability of implementing this system commercially.
  - Development of a Bi-phasic CAS System:
    - A Bi-phasic CAS system could be developed to initiate a stun with an argon-gas mix until the pigs are unconscious, and then cause death by the addition of HCC[36].
    - This would remove the aversion effect of CO_2 in initiating a stun, allow automation to ensure effective stuns, allow group stunning, minimise excess costs associated with 90% argon stunning facilities, maintain carcass quality, and operator handling safety.
    - However, more research is required to determine if existing HCC stunning facilities can be fit with additional argon units, if there is any interaction between argon and CO_2 in the stunning chamber and physiologically which may affect the production of an effective stun and the cost to implement and run a mixed-gas system.
- Overall, there needs to be collaboration between all stakeholders in academia and industry to rapidly develop high welfare and cost-effective stunning systems appropriate for commercial use in the UK.

The VPRF would like to thank Rachel Barham, who at the time of writing was a 4th year veterinary student studying at the University of Cambridge, input into researching and helping write part of this briefing.

[36] Catrina Prince Pig Stunning Brief 2019

Stunning Method		Group vs Individual Stun	Aversion to stimuli	Induce death?	Time to loss of Consciousness	Carcass Quality	Human Error Factor	Supply issues
Controlled Atmospheric Stunning	**High Concentration CO2**	Group	Yes – 'mild to severe'[34]	Yes - hypercapnic hypoxia[32]	Depends on the data source – some suggest up to 15 seconds[34], whereas others suggest significantly longer, between 30-60 seconds[9].	Meat quality tends to be good[10]. Associated with increased risk of lumbar muscle hameorrahges[11].	Automated	Yes
	Argon mixes	Group	No[34]	Yes - Hypoxia[12]	Average of 35 seconds[37], but need exposure over 7 minutes due to rapid regaining of consciousness if removed early[12].	Can have links to PSE which reduces carcass quality[11]. Pigs undergo anoxic convulsions which impact carcass meat.		
Electrical	**Head-only**	Individual – requires restraint[21].	No[21] (although 'aversive' to being separated from their group[23]).	No – causes an epileptic seizure[21]	Instant provided correct current is applied and electrodes are in the correct position.	Associated with blood splash (pre-stun shocks), broken bones (shoulder/vertebrae) from muscle tension, and tonic and clonic phase (paddling/kicking). Any carcass damage is associated with PSE[26].	Relies on well-maintained equipment and correct positioning of electrodes. Automated stunners are being developed.	Powercuts?
	Cardiac-only			Yes – cardiac arrest[21]		Associated with blood splash (pre-stun shocks) and broken bones (shoulder/vertebrae) from muscle tension. Any carcass damage is associated with PSE[26].		
	Combination			Yes – cardiac arrest[21]				
Low Atmospheric Pressure Stunning		Group	Yes[31] – equal to CO_2 aversion[32]	Yes – hypobaric hypoxia[29]	Depends on decompression rates which are yet to be determined. Some suggest total killing cycle is 9-14 minutes.[28]	Slower decompression times are associated with whole-body convulsions which reduce carcass quality[30].	Automated	n/a

[37] E.M. Claudia Terlouw, Véronique Deiss, Thierry Astruc, Stunning of pigs with different gas mixtures: Behavioural and physiological reactions, Meat Science, Volume 175, 2021, 108452, ISSN 0309-1740, https://doi.org/10.1016/j.meatsci.2021.108452.