

Time for action – carbon dioxide can and should be replaced as a method for stunning pigs

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Overview

Why is CO₂ an
(intractable)
animal welfare
problem?

What are the
alternatives?

What next?

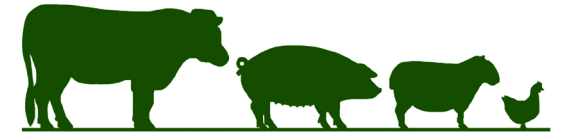




The HSA's starting point

The Humane Slaughter Association's position regarding the slaughter of all animals is that they should be killed as humanely as possible with every reasonable effort made to minimise pain, suffering and distress.

We will actively work to promote and help develop more humane methods for pig slaughter.



Humane Slaughter Association

CO₂ stunning for pig slaughter

- Most pigs slaughtered using CO₂ stunning
- Advantages
 - Efficient
 - Pre-stun handling can be high-welfare

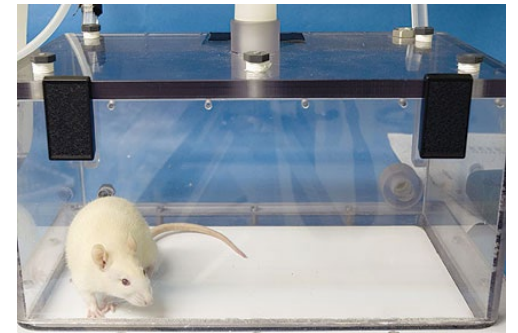
There is no question that CO₂ is a welfare problem

Extensive evidence in pigs



By courtesy of Mohan Raj

Even more extensive evidence in other mammals



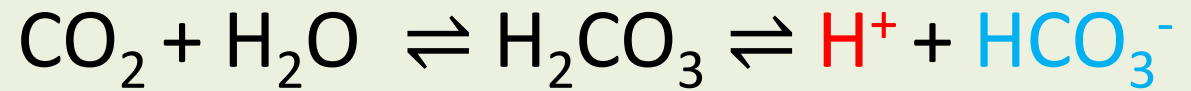
© Huw Gollidge



Video by courtesy of Dr Mohan Raj/Bristol University

Raj, A.B.M. and Gregory, N.G. 1995. Welfare implications of gas stunning pigs 1.
Determination of aversion to the initial inhalation of carbon dioxide or argon. *Animal Welfare*, 4: 273-280.

CO₂ welfare challenges are well-understood



Causes pain > 50% CO₂

Causes Anxiety > 5-10% CO₂

There is no way to use CO₂ for slaughter without causing animal welfare issues.

Evidence from the Pre-Clinical Pharmacology Literature

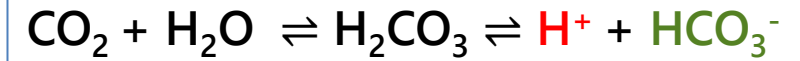
CO₂ is widely used in humans and rodents to model human panic disorder and anxiety.

Extensive evidence shows panic-, or anxiety-like reactions in response to low concentration CO₂ challenges in both humans and rodents.

Multiple brain mechanisms for CO₂ chemosensation and panic-like reactions have been identified.

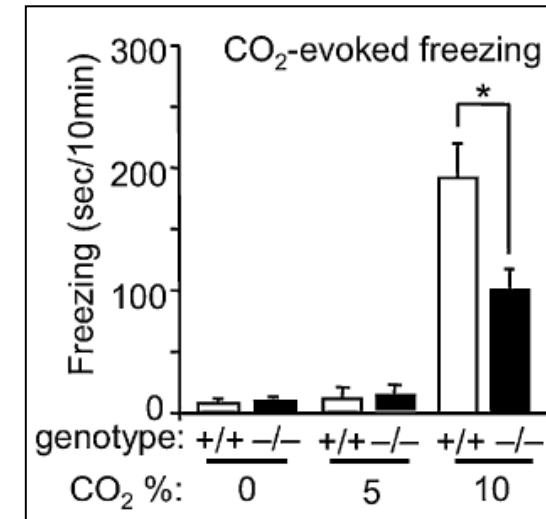


ASIC1a Channels sense CO₂-induced acidosis in the brain



One mechanism is mediated through ASIC1a ion channels

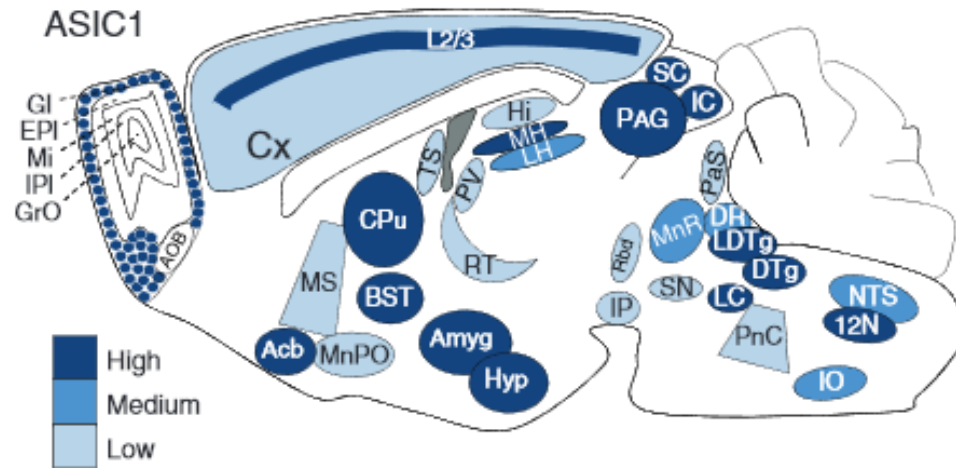
ASIC1a knockout mice have attenuated fear responses



Ziemann et al. (2009). "The amygdala is a chemosensor that detects carbon dioxide and acidosis to elicit fear behavior." *Cell* 139, 5: 1012–1021.

Ziemann et al. (2009). "The amygdala is a chemosensor that detects carbon dioxide and acidosis to elicit fear behavior." *Cell* 139, 5: 1012–1021.

Anatomical Substrates - ASIC1a is strongly expressed in areas associated with anxiety/panic



Price, M., et al. (2014). "Localization and Behaviors in Null Mice Suggest That ASIC1 and ASIC2 Modulate Responses to Aversive Stimuli." *Genes, Brain, and Behavior* 13(2): 179–94.

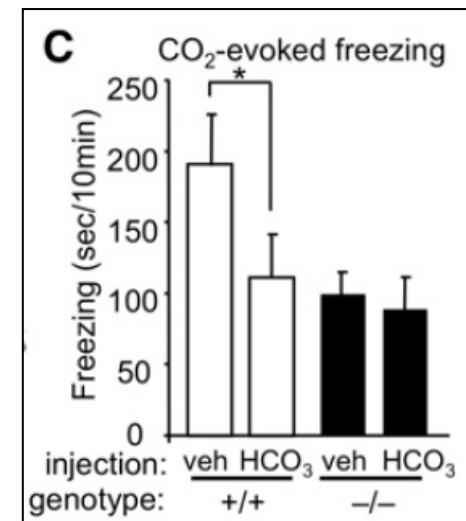
Response mediated in areas involved in anxiety including the basolateral amygdala (freezing), bed nucleus of the stria terminalis (BNST) and/or periaqueductal grey (freezing/escape).

Taugher, R et al. "The Bed Nucleus of the Stria Terminalis Is Critical for Anxiety-Related Behavior Evoked by CO₂ and Acidosis." *Journal of Neuroscience* 34(31) 10247–55.

Ziemann et al. (2009). "The amygdala is a chemosensor that detects carbon dioxide and acidosis to elicit fear behavior." *Cell* 139, 5: 1012–1021.

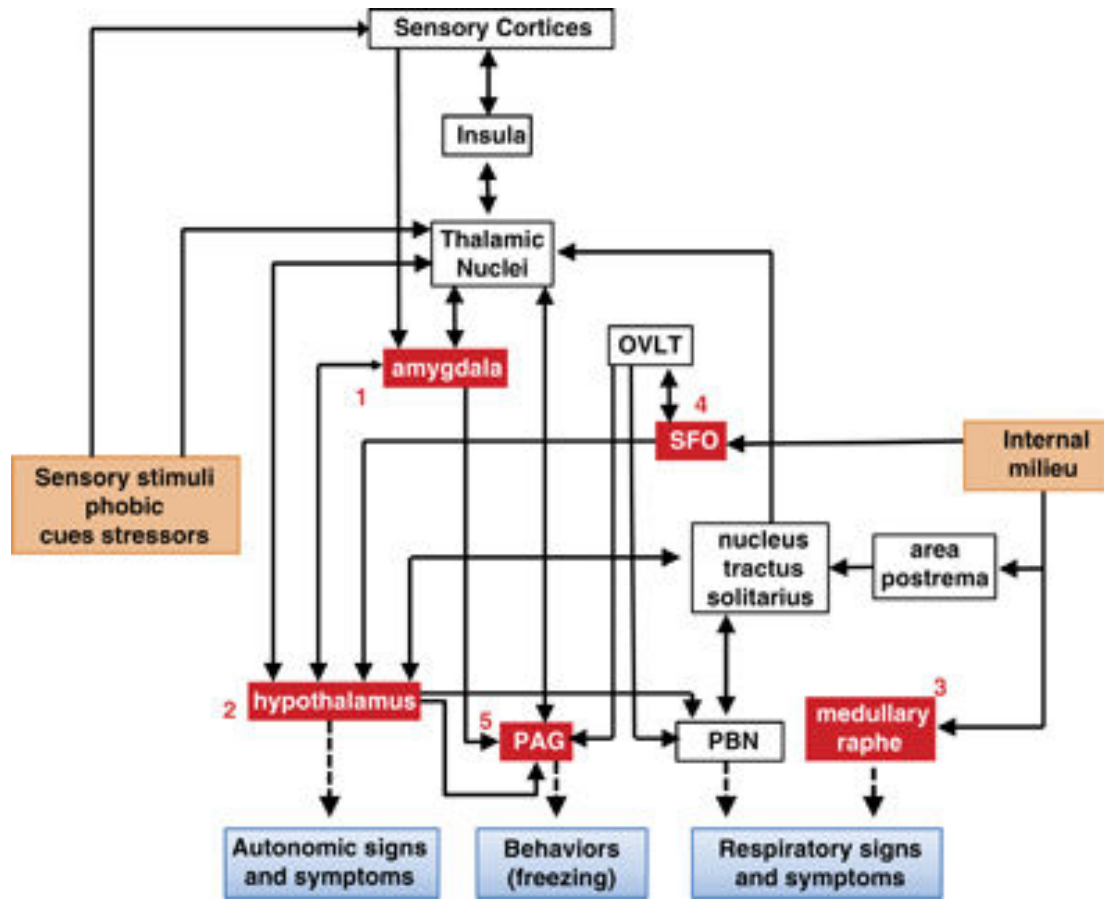
Kreple, C, (2015) PhD Thesis, U. Iowa

Basolateral Amygdala



Ziemann et al. (2009). "The amygdala is a chemosensor that detects carbon dioxide and acidosis to elicit fear behavior." *Cell* 139, 5: 1012–1021.

Mechanisms of CO₂-Induced Anxiety



- 1: acid sensing ion channels (ASICs) in the amygdala,
- 2: orexin neurons in the hypothalamus
- 3: serotonergic neurons in the medullary raphe
- 4: T-cell death-associated gene-8 receptor in the subfornical organ (SFO)
- 5: hypoxia-sensitive chemosensory neurons in the periaqueductal gray (PAG).

Vollmer, L. et al. (2015). "Acid–base Dysregulation and Chemosensory Mechanisms in Panic Disorder: A Translational Update." *Translational Psychiatry* 5(5), e572. <https://doi.org/10.1038/tp.2015.67>.

Mechanisms - Summary

There is robust behavioural & mechanistic evidence that CO₂ at concentrations >10% cause anxiety or panic like states in both animals and humans.

REVIEW ARTICLE

Open Access

The role of acid-sensitive ion channels in panic disorder: a systematic review of animal studies and meta-analysis of human studies

Laiana A. Quagliato¹, Rafael C. Freire¹ and Antonio E. Nardi¹

Quagliato, L.A., Freire, R.C., and Nardi, A.E. (2018). The role of acid-sensitive ion channels in panic disorder: a systematic review of animal studies and meta-analysis of human studies. *Transl. Psychiatry* 8.

“According to this systematic literature review, acid sensitive channel antagonists decreased escape behavior in preclinical animal models of PD.... Acid sensitive channels may play an important role in the pathophysiological mechanisms of PD”

CO₂ Exposure causes fear/anxiety in humans

A single breath of 35% CO₂ causes panic attacks in susceptible subjects

Breathing 7.5% CO₂ (normoxic) causes anxiety in humans (Bailey et al. 2005).

Rating	Peak air	Peak CO ₂
Anxious	2 (2.1)	25 (5.8) ^b
Fear	1 (2.9)	24 (4.5) ^b
Feel like leaving	3 (2.5)	23 (5.8) ^b
Happy	-10 (2.9)	-27 (4.0) ^c
Irritable ^a	2 (2.1)	16 (6.9) ^d
Nervous ^a	5 (2.3)	17 (3.4) ^c
Paralysed	4 (2.6)	15 (4.2) ^c
Relaxed	-13 (5.5)	-35 (4.9) ^b
Tense	4 (2.9)	29 (5.1) ^b
Worried ^a	1 (1.6)	18 (4.7) ^c

Values are expressed as mean (sem); *n* = 20.

Bailey, J.E., et al. "Behavioral and Cardiovascular Effects of 7.5% CO₂ in Human Volunteers." *Depression and Anxiety* 21, no. 1 (2005): 18–25.

Johnson, P et al.. "Induction of C-Fos in 'panic/defence'-Related Brain Circuits Following Brief Hypercarbic Gas Exposure." *Journal of Psychopharmacology* 25, (2011): 26–36.

Perna, G et al. (1996). "35% CO₂ Challenge in Panic and Mood Disorders." *Journal of Affective Disorders* 33, no.3 : 189–94.

Trigger Warning

Disturbing images





UK PIGS
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IN GAS
CHAMBERS
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Ahead of [#WorldFarmAnimal](#) day, we're highlighting what life is like for the billions of animals reared in factory farms.

Today the focus is on pigs - intelligent and social creatures who are often confined to cramped, barren conditions in factory farms.

Sign our petition to [#EndIt](#) 🖱️ <https://ciwf.end.it/sign/>



Editorial

This little piggy wants better welfare

THIS issue of *Vet Record* focuses on various elements of the welfare of intensively farmed pigs. And what the feature on pp 323–327, which looks at the use of farrowing crates, shows is how difficult it is to bring about improvements.

Farrowing crates – a production system that restricts a sow's ability to move but still allows the piglets to access her – were introduced to reduce piglet deaths resulting from crushing by the sow. But any system that restricts an animal from being able to do anything but stand up and lie down for a long period (typically around five weeks) imposes a high welfare cost on the animal affected. In this case, the sow.

An alternative being suggested is the use of temporary farrowing crates. Here the sow is restricted just for the period during which the piglets are at most risk of being crushed, reducing the amount of time the sow spends in the crate to about five days. While this surely improves the situation for the sow, uptake has been slow.

Sadly, it's easy to see why. Changing production systems is expensive so farmers must be confident that any changes they make are the right ones. For example, clarity is needed on whether legislation will dictate the size of pens, and, if so, what dimensions will be specified, so farmers can be sure that any modifications they make, or new pens that they build, will satisfy upcoming legal requirements. Many pig farmers also, rightly or wrongly, feel stung by changes that were brought in when sow stalls – which confined sows during the gestation stage – were banned in the UK, but not elsewhere, leading to an influx of cheaper pig meat from other countries. Whether this action brought about a decline in pig farming in the UK is debatable but the perception that it did is another barrier to farmers making changes.

There are other factors at work too. In investigating this issue, *Vet Record* heard repeated reports of farmers having planning applications rejected when seeking to make more space to raise the same number of pigs (as opposed to increasing the number of pigs they farmed). The result might have been different if those involved in assessing

such applications understood the welfare benefits of increasing housing provision for the pigs.

Elsewhere in this issue, research summarised on p 336 explores the rates of ear and tail biting among tail docked and undocked pigs. One of the findings was that pigs that were docked were more likely to have ear lesions. So the problem of biting was not solved by removing pigs' tails, rather it was directed elsewhere – in this case to the ears.

With findings like this in mind, some view the keeping of pigs in an intensive but welfare-positive manner as impossible. Among them is Steve McCulloch, who in a debate article on p 343, calls for the veterinary profession to withdraw its support of intensive pig farming globally. McCulloch argues that there is no way to farm pigs intensively to a welfare standard that is acceptable. Undoubtedly there are those who would counter that the UK's system is better than others elsewhere in the

world that, for example, still use sow stalls, and those involved should therefore be encouraged to improve welfare gradually.

What is not in doubt is that, globally, pig meat will remain popular. China alone consumes nearly 60 million tons of pork a year – accounting for about 40 per cent of global consumption. In the UK, even though pork consumption has been falling, the British love of bacon and sausages means pork is still popular (1.7 million tonnes consumed in 2017, with only about 40 to 50 per cent being produced in the UK).

Pig farming is not going to disappear overnight, but no one is arguing that farrowing crates are good for sow welfare, or that many other aspects of pig farming cannot be improved. A way must be found to better the lot of animals in intensive systems.

Suzanne Jarvis

VET RECORD EDITORIAL POLICY

BVA grants editorial freedom to the Editor of *Vet Record*. The views expressed in the journal are those of the authors and may not necessarily comply with BVA policy

DEBATE

'The veterinary profession must condemn intensive pig farming'

Steven McCulloch argues that the global intensive pig farming industry does not meet the welfare needs of pigs and that the veterinary profession should and must withdraw all support.

AROUND the world society is increasingly concerned about how farmed animals are treated to produce food. Globally, intensive pig farming is characterised by caged breeding sows, piglet mutilations, squalid environments for growing pigs and finished pigs suffering at slaughter. Given the role and responsibilities of the veterinary profession, we must withdraw all support for the industry, and indeed condemn it.

Human society justifies consuming farmed animals on the condition that they have a good life and a humane death. Legislation across much of the world is based on the unnecessary suffering principle; we are permitted to use animals, but any suffering caused must be necessary.¹ The veterinary profession has a fundamental duty to protect animal welfare and safeguard public health, based on scientific evidence.

Pigs are a highly sentient, social and intelligent species. They have a range of strongly motivated natural behaviours including rooting and digging to explore their environments and nest building before farrowing. Emotionally and cognitively, pigs are comparable to family pet dogs, and they have intelligence levels similar to three-year-old children.

Globally, around 1.5 billion pigs are slaughtered each year. China (700 million), the EU (410 million), and the USA (128 million) are the largest pig producers, while 10 million pigs are slaughtered annually in the UK.

Sow stalls/gestation crates confine pregnant pigs, normally for the duration of their 115-day pregnancy. Almost all sows in the USA and a growing number in China are kept in these cages, able to

stand up and lie down, but unable to turn around. Donald Broom, the world's first professor of animal welfare, has called stalls the 'most extreme cruelty' to animals. John Webster, architect of the five freedoms, compared stalls to solitary confinement for an incarcerated human.²

The EU permits sow stalls for four weeks at the start of pregnancy, while the UK has prohibited them outright. Farrowing crates – legal and routinely used in China, the EU, the USA and the UK – like stalls do not meet the welfare needs of sows and they are not necessary to reduce piglet mortality³, as has been claimed.

Days after birth, piglets undergo tail docking, teeth clipping and castration, mutilations almost always carried out without anaesthesia or analgesia. Piglets' tails are amputated to prevent tail biting, associated with barren environments and high stocking densities. Legislation in the EU and UK prohibits tail docking, with an exemption under veterinary certification. Despite the ban, a staggering 90 per cent of EU pigs and 70 to 80 per cent of UK pigs still have their tails amputated.

Piglets, weaner and growing pigs suffer from conditions like diarrhoea, pneumonia and meningitis. Such conditions are often associated with the stresses caused by early weaning and keeping pigs in squalid and unsanitary environments. Large quantities of antibiotics are used to prevent and treat such conditions, and resistance to antibiotics critically important for human medicine has been found in pigs.

Generally, slaughter legislation requires farmed animals to be stunned, based on the principle of providing a humane death, with exemptions for Jewish and Muslim faiths. In 2020 the European Food Safety Authority advised against using carbon dioxide, stating that it caused 'pain, fear and respiratory distress'.⁴ Despite scientific

recommendations, the vast majority of pigs continue to be 'stunned' using carbon dioxide in the EU, the USA and the UK.

Breeding sows in stalls and crates, painful mutilations of piglets, growing pigs in squalid environments and suffocation before slaughter of finished pigs – considered alone, any one of these practices should raise serious questions about continued veterinary support for the pig industry. But these practices are all widespread in global intensive pig farming. Given the nature of the veterinary profession, and based on our own principles to ensure welfare, we must surely condemn the industry outright.

Pigs evidently suffer on a massive scale. But is the suffering necessary? Followers of some religious faiths and vegetarians are living testament to the fact that we do not need to consume pigs. Meat alternatives in supermarkets serve as a daily reminder that consuming pigs is not necessary. Any claim that the veterinary profession should support intensive pig farming, due to public demand, sells out the highly sentient, social and intelligent pigs that we are duty-bound to protect.

Globally, intensive pig farming has raced to the bottom and is locked in. Calls for reform in one country are opposed because it risks importing pork produced in even worse conditions abroad. The pig industry lobbies vociferously against method of production labelling, so consumers continue to be unaware of the sordid origins of their dinner. Governments fail to heed expert calls to ban carbon dioxide, openly stating that stunning methods that ensure welfare are not economically viable.⁵

It is the veterinary profession's responsibility to protect farmed animals on farm, in transport and at slaughter. To protect pigs, the veterinary profession must simply advocate for society to keep them off our plates. ●



Pigs evidently suffer on a massive scale

References

1. FAWC. Farm animal welfare in Great Britain: Past, present and future. 2009. <https://bit.ly/3N9yeM5> (accessed 10 October 2024)
2. The Humane Society of the United States. Scientists and experts on gestation crates and sow welfare. 2012. <https://bit.ly/4eEf3R8> (accessed 14 October 2024)
3. McCulloch, S. Banning farrowing crates in the UK: transitioning to free farrowing to meet the welfare needs of pigs. 2022. <https://bit.ly/4835odo> (accessed 10 October 2024)
4. EFSA Panel on Animal Health and Welfare, Nielsen SS, Alvarez J, et al. Welfare of pigs at slaughter. *EFSA Journal* 2020;18:e06148
5. Eurogroup for Animals. Stunning/killing of pigs with high concentrations of CO₂. 2019. <https://bit.ly/4eCn1Dm> (accessed 10 October 2024)

Everyone hates CO₂

The UK Farm Animal Welfare Committee recognised as early as 2003 that CO₂ should be phased out.

And in 2004 the European Food Safety Authority also raised concerns about the use of CO₂ to kill pigs

2020 EFSA Scientific Opinion – “Exposure to CO₂ at high concentration ... **should be replaced** by exposure to other gas mixtures that are less aversive.”

2024 HSA – “...it is **essential** that other alternatives are adopted without undue delay”



Something has to change, What are the alternatives?

~~Low Atmospheric Pressure Stunning (LAPS)~~

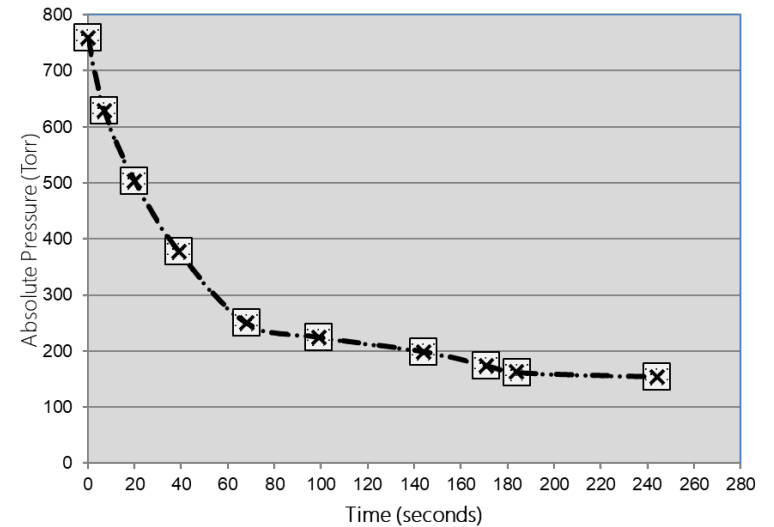
Electrical stunning with improved handling

Inert Gas (Ar, N₂, He...)

Low Atmospheric Pressure Stunning

Gradual reduction in atmospheric pressure over several minutes. Final pressure – 20kPa (11,500m altitude equivalent)

Approved for chicken slaughter in the EU.



LAPS Research

In 2018 Defra and HSA supported research to investigate whether LAPS was a humane alternative.

Conclusion

"Collectively, our results show that both LAPS and CO₂ stunning are associated with several indicators of poor welfare and are equally aversive to pigs."

McKeegan et al. 2024



Improved Electrical Stunning

Electrical stuns can be humane

But, pre-stun handling is sub-optimal

Improved (?automated) handling of pigs in groups could improve welfare.

Improved methods developed by EyesOnAnimals – need validation.

Ongoing work as part of PigStun project.



Image ©HSA

Inert Gas

Argon, nitrogen, helium etc. can be used to kill animals by displacement of air.

Argon may be the simplest to use due to similar density to CO_2 (N_2 and He are lighter and harder to contain)

Should be used in pure form, **not** mixed with CO_2



Video by courtesy of Dr Mohan Raj/Bristol University

Raj, A.B.M. and Gregory, N.G. 1995. Welfare implications of gas stunning pigs 1.
Determination of aversion to the initial inhalation of carbon dioxide or argon. *Animal Welfare*, 4: 273-280.

Current State of Play

CO₂ stunners can (and have been) retrofitted to use argon.

Cost reported to be ca. 50,000 Euro

Ongoing gas costs also higher
⇒ 1 Euro Cent per kg pork

Meat quality appears to be acceptable

NEWS ARTICLE | 20 March 2023 | European Health and Digital Executive Agency | 1 min read

HaDEA signs a grant agreement with PigStun consortium for the development of non-aversive stunning methods for pigs



Barriers to uptake

Throughput (pigs take longer to lose consciousness in argon)

Requirement for pigs to be dead (UK not EU)

Cost

Carbon footprint

Next Steps

~~More research needed~~

More implementation needed – these are engineering problems

The industry needs to:

- Implement solutions
- Or demonstrate conclusively why they can't be implemented

Preliminary workshop program (Tuesday, 19 th of November)	
Chair: <i>Dr. ir. Hans Spoolder, Wageningen Livestock Research</i>	
0900 - 0930 hrs	Registration, Welcome Coffee
Project Introduction	
0930 - 0950 hrs	The 'PigStun' Project: Objectives and overview (<i>Dr. Ing. Marien Gerritzen, Wageningen Livestock Research, The Netherlands</i>)
Description of the 4 systems in the 'PigStun'-Project	
0950 - 1005 hrs	Inert Gas Retrofit System (<i>Dr. Jonas Knöll, Friedrich-Loeffler-Institut, Germany</i>)
1005 - 1020 hrs	Helium Stunning System (<i>Sebastian Zimmermann, Max-Rubner-Institut, Germany</i>)
1020 - 1035 hrs	Box System (<i>Johan Meulendijks, Marel Red Meat BV, The Netherlands</i>)
1035 - 1050 hrs	Improved Electric stunning process (<i>Dr. Ing. Marien Gerritzen, Wageningen Livestock Research, The Netherlands</i>)
Coffee Break (20 min)	
Across analyses: results and initial conclusions	
1110 - 1135 hrs	Animal Welfare (<i>Dr. Antonio Velarde, Institute for Food and Agricultural Research and Technology, Spain</i>)
1135 - 1200 hrs	Meat Quality (<i>Dr. Lars Kristensen, Danish Meat Research Institute, Denmark</i>)
1200 - 1230 hrs	Social, economic and environmental impacts (<i>Prof. Dr. Jan Tind Sørensen, Aarhus University, Denmark</i>)
Lunch (60 min)	
1330 - 1350 hrs	Ease of conversion (<i>Rikke Bonnichsen, Danish Meat Research Institute, Denmark</i>)
Interviews	
1350 - 1410 hrs	Insights from case slaughterhouses on the alternatives (<i>Prof. Dr. Hanne Kongsted, Aarhus University, Denmark</i>)
Coffee Break (20 min)	
Recommendations	
1430 - 1600 hrs	Common discussion about first hints for recommendations



Next Steps - HSA

Is working and will continue to work with industry to find practical solutions.

Would consider supporting R&D to implement a solution but would strongly advocate for support from industry.

Will advocate for regulatory change.

Will be very disappointed if change has not come about after another 30 years!

Conclusion

CO₂ for stunning is not humane and needs to be consigned to history

Alternatives are available.

This is not a moonshot! It shouldn't have taken >30years to make progress.

We shouldn't let perfection be the enemy of good

The onus is on the industry to make this work or provide convincing evidence why it won't



