WELFARE IMPLICATIONS OF THE GAS STUNNING OF PIGS 1. DETERMINATION OF AVERSION TO THE INITIAL INHALATION OF CARBON DIOXIDE OR ARGON

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The aversive effects of 90 per cent argon in air, 30 per cent carbon dioxide in air or 90 per cent carbon dioxide in air were investigated in slaughter weight pigs. Aversion was assessed from their reluctance to enter the three gaseous atmospheres to obtain a reward (apples). The pigs did not show any aversion to the inhalation of 90 per cent argon in air. The majority of the pigs did not show aversion to the presence of 30 per cent carbon dioxide in air. By contrast, the inhalation of 90 per cent carbon dioxide was aversive to the majority of the pigs. Fasting them for up to 24h prior to testing did not overcome the pigs' reluctance to enter an atmosphere containing 90 per cent carbon dioxide.

Keywords: *animal welfare, argon, aversion, carbon dioxide, inhalation, pigs, stunning*

Introduction

When pigs are killed for human consumption they must first be rendered unconscious (ie insensible to pain) by stunning them with either an electric current or carbon dioxide. Then they can be slaughtered by exsanguination. In the case of electrical stunning, the current is applied across the head through a pair of tongs placed on either side of the head. In the case of carbon dioxide stunning, the pigs are loaded either singly (Compact stunner) or in pairs (Combi stunner) into a cradle which is then lowered into a well containing the gas.

High voltage electrical stunning of pigs (with 1.3 ampere) has been recommended because it will guarantee the induction of unconsciousness. However, practical experience has shown that high currents such as this can lead to carcass convulsions, which might impede the bleeding operation, and also broken bones and haemorrhaging in muscles. Carbon dioxide stunning of pigs produces relaxed carcasses enabling prompt bleeding out to be performed and also reduces or eliminates the quality defects (Larsen 1983). Because of this, some abattoirs have recently changed to using carbon dioxide stunning rather than electrical stunning. With carbon dioxide stunning, the UK legislation requires exposure to a concentration of not less than 70 per cent by volume of carbon dioxide.

There is concern among welfarists and some legislators that carbon dioxide is not the best gas to use for stunning pigs. Blomquist (1957), who developed this method, reported that

unrestrained pigs ran around for the first 15s during carbon dioxide stunning. Dodman (1977) also found some degree of excitation and violent reactions in a few pigs, but concluded on subjective grounds that carbon dioxide stunning is better than badly performed electrical stunning. More recently, experience in man has shown that it is unpleasant to inhale carbon dioxide at high concentrations, as it is an acidic gas and pungent in odour, and it can cause a profound sense of breathlessness (Gregory *et al* 1990). It is clear that carbon dioxide stunning of pigs remains a controversial issue and further research into the welfare aspects of the subject is warranted. The present study set out to determine whether carbon dioxide stunning was aversive for the majority of pigs, and in the same experiments some alternative stunning methods were also investigated. From the commercial standpoint any alternative gas stunning method should retain the meat quality advantages of carbon dioxide stunning, and from the welfare standpoint it should reduce or eliminate the unpleasantness associated with carbon dioxide.

Experience with the inhalation of argon suggests that this gas is odourless and tasteless, and therefore the induction of anaesthesia by anoxia with this gas may not be unpleasant. However, since argon is one of the inert gases occurring naturally in minute quantities and extracted from atmospheric air, it is thought to be more expensive than carbon dioxide gas which is a byproduct from distilleries.

Nevertheless, it was found in chickens that given a free choice three out of eight hens avoided a feeding chamber containing 48 per cent carbon dioxide in air, whereas six out of six test hens entered the feeding chamber when it contained 90 per cent argon in air and were killed with this gas (Raj unpublished observation).

Another option would be to use a low concentration of carbon dioxide ($< 30\%$) in argon. Research has shown that this gas mixture, in comparison with anoxia alone or a high concentration of carbon dioxide in air, caused a rapid loss of brain function in chickens (Mohan Raj *et al* 1992) and turkeys (Raj & Gregory 1993). This added weight to the argument that this gas mixture was an acceptable stunning method on humanitarian grounds.

However, the effectiveness of the stun induced with this gas mixture and the pungency effect of carbon dioxide at low levels have not been investigated in pigs. This study was conducted to determine whether the initial inhalation of argon, 30 per cent carbon dioxide in air or 80 to 90 per cent carbon dioxide in air would be aversive to the pigs.

Materials and methods

In this study the aversive effects of inhaling 90 per cent argon in air (anoxia), 30 per cent carbon dioxide in air, and 90 per cent carbon dioxide in air in the presence of a reward, (apples) were investigated using two groups of adult entire male pigs in separate trials. During this study, the liveweight of the pigs ranged from 55 to 72kg. A 30 per cent carbon dioxide in air atmosphere was chosen mainly to determine if at this concentration of carbon dioxide the pigs show any aversion. If there was no aversion, it could be inferred that it might be acceptable to use it in association with anoxia to stun them (ie carbon dioxide and argon mixture).

Trial one involved three Duroc pigs and three Large White pigs, and trial two involved 10 different pigs – six Duroc and four Large White. The experimental protocols used in the two trials are presented in Table 1.

Table 1 Experimental protocol.

	Trial 1	Trial 2
No of pigs	6	10
Day 1	air	air
Day 2	argon	argon
Day 3	air	air
Day 4	90% CO_2 in air	30% CO_2 in air
Day 5	air	air
Day 6	air	air
Day 7	30% CO_2 in air	90% CO_2 in air
Day 8	90% CO_2 in air after 16h fasting	air
Day 9	90% CO_2 in air after 18h fasting	90% CO_2 in air after 24h fasting
Day 10	-	air

A perspex box fitted with a flap door, gas inlets, gas sampling tube and a wooden feed trough, was used as the experimental feeding plus gassing apparatus in both the trials. The gas inlet was placed under the feed trough to avoid the gas being blown directly into the pig's face while it was feeding in the box. The gas sampling tube was placed inside the box just above the feed trough.

The pigs were kept in a pen adjacent to the experimental pen and fed at 0800, 1230 and 1730h. They were tamed for a month by a person sitting in the pen and feeding them with chopped apples. Prior to commencement of the trials, between the morning and the midday feed, the pigs were trained for 15 days to push the flap door and feed for three minutes on chopped apples provided inside the box. By the end of this familiarization period the pigs had got used to the handling routine and learnt to feed on the apples without any hesitation.

On the control days, compressed air from a cylinder was supplied to the box so that the pigs did not obtain any auditory cue during the experimental days. On the experimental days, carbon dioxide (vapour delivery) or argon was supplied to the box until a desired level was established inside the box, and then a pig was allowed to enter the experimental pen and feed on some chopped apples provided inside the box. A steady flow of gas was maintained during feeding. However, while using argon the residual oxygen level increased from 2 to 18 per cent; and while using carbon dioxide the concentration fell from 90 per cent to a minimum of 15 per cent towards the end of the first minute of a pig entering the box. The gas concentrations were monitored using infrared and magnetic sensors for carbon dioxide and oxygen respectively (Servomex Ltd, Crowborough). The behaviour of pigs was recorded for three minutes on a videotape, and was subsequently used for determining whether the gas caused any aversion. The following behaviour patterns were considered to be indicators of aversion, and the likely reasons are given in each case:

a) initial withdrawal reaction of the pigs: ie if the presence of the gas was disturbing to the pigs (for example pungent) and they withdrew their heads from the box immediately,
b) aversion to prolonged exposure: ie if the pigs experienced distress (for example breathlessness) leading to withdrawal of their heads prior to the onset of loss of posture (a behavioural indicator of the onset of unconsciousness),

c) avoidance behaviour: if one of the above effects resulted in the pigs avoiding the box altogether, and
d) learnt behaviour: if the pigs developed any severe aversion during their initial experience with a gas they might recall it, and thereafter hesitate to put their heads into the box on the following day when it contained only atmospheric air.

Behavioural signs, such as coughing, sneezing and loss of posture were also noted for each pig.

The time to withdrawal of the pigs' heads after the first entry into the box and the total time spent feeding in the perspex box were determined using a stopwatch. These two parameters were considered to be useful in determining the aversion quantitatively. Therefore, data from the two trials were separately subjected to Kruskal-Wallis analysis to determine the differences between the treatment gases. The expression of avoidance and learnt behaviours were subjectively described in the results.

Results

Trial 1

The results of trial 1 are presented in Table 2. On day one, and on subsequent days when the box contained air, none of the pigs hesitated to enter the perspex box to obtain the reward, and they spent a high proportion of the available time feeding in the box. When the box contained 90 per cent argon, the time to first withdrawal of the head was shorter. This was mainly because all the six pigs subjected to this treatment either became unsteady or lost their posture while they were feeding inside the box, and the withdrawal of the head was not necessarily a co-ordinated voluntary movement. None of the pigs showed hyperventilation whilst inhaling argon presented inside the box. All pigs re-entered the box immediately after regaining a steady gait. The day after the argon treatment when the box contained air, none of the pigs hesitated to enter and feed in the box.

Table 2 **Aversion to the presence of gaseous atmospheres in the perspex box in trial 1 (n = 6) as determined during 180s exposure time.**

	Time to first withdrawal of head (seconds)		Total time spent in the box (seconds)	
	median	**mean rank**	**median**	**mean rank**
Day 1, air	167	40	179	39
Day 2, argon	16	30	171	34
Day 3, air	180	44	180	42
Day 4, 90% CO_2 in air	3	16	14	15
Day 5, air	95	35	178	38
Day 6, air	180	43	180	43
Day 7, 30% CO_2 in air	7	18	78	17
Day 8, 90% CO_2 in air after 16h fasting	2	12	5	10
Day 9, 90% CO_2 in air after 18h fasting	2	10	19	10

Data were subjected to a Kruskal-Wallis test (H = 36.34 for time to first withdrawal of head; H = 38.49 for the total time spent in the box; $df = 8$). Chi-square at 5% confidence level = 15.51.

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When 90 per cent carbon dioxide was present in the box (day 4), the time to first withdrawal of their heads was immediate and the pigs also spent significantly less time feeding in the box. Two Large White pigs, which primarily contributed to the total time spent in the box, repeatedly attempted to feed but withdrew their heads when they began to hyperventilate and their gait eventually became unsteady. The other four pigs also made repeated attempts to re-enter but on most occasions they withdrew their heads in less than two seconds. The day after the carbon dioxide treatment, three out of the six pigs hesitated to enter the box.

When 30 per cent carbon dioxide was tested in the box, two Duroc pigs withdrew their heads immediately after entry, three pigs (one Duroc and two Large Whites) withdrew their heads at the time of the onset of hyperventilation and only one of them entered the box again. One Large White pig withdrew its head once due to the onset of loss of posture, and it re-entered on regaining its balance.

When 90 per cent carbon dioxide was tested after 16 hours of fasting five out of six pigs withdrew their heads immediately after their first entry, and during their subsequent attempts to feed (1 to 7 attempts) they stayed in the box for less than a second. The only Large White pig which kept its head in the box stayed there for 10s after the first entry, but withdrew when it began to hyperventilate. It made six more attempts to feed, each lasting until the time to the onset of hyperventilation. This pig showed a similar behaviour when it was subjected to the test after 18h of fasting. Increasing the number of hours of fasting to 18h did not force the other five pigs to feed in the box. They withdrew their heads immediately after their first entry. Two of them did not make any further attempts to enter the box, and the other three attempted up to seven times, each of them lasting for less than two seconds. The total time spent in the box was very similar in all the three 90 per cent carbon dioxide treatments.

Trial 2

The behaviour of the pigs during the control days (air) and in the presence of argon inside the box was similar to that in trial 1 (Table 3). However, only three pigs showed loss of posture during feeding when argon was present in the box, and they re-entered after the resumption of balance. None of them hesitated to enter the perspex box on the control (air) day after the argon treatment.

When 30 per cent carbon dioxide was present in the box, one Duroc and one Large White pig fed on the apples in the box continuously for three minutes, however, they were hyperventilating. All the other pigs withdrew their heads at the time of the onset of hyperventilation, but re-entered within five seconds. The total time spent in the box during 30 per cent carbon dioxide treatment was very similar to that recorded for the control days. None of the pigs hesitated to enter the box on the following control day (air).

When 90 per cent carbon dioxide was present in the box all the pigs, except one Large White, withdrew their heads in less than five seconds. One Large White pig walked out of the experimental pen and hesitated to return. One of the Large White pigs stayed in the box and fed on the apples continuously for the entire three minute observation period, even though it was hyperventilating. This single pig contributed to the relatively higher median value for the total time spent in the box compared to that in Trial 1. Two pigs (one Duroc and one Large White) spent less than 20s in the box. Overall, the total time spent in the box

was significantly lower when 90 per cent carbon dioxide was present. Two Duroc pigs and one Large White pig showed intermittent sneezing when they withdrew their heads from the box. One Large White pig showed continuous coughing for about 15s, however, this was 50s after the first entry and during that time it withdrew its head from the box on six occasions.

Table 3 **Aversion to the presence of gaseous atmospheres in the perspex box in trial 2 (n = 10) as determined during 180s exposure time.**

	Time to first withdrawal of head (seconds)		Total time spent in the box (seconds)	
	median	**mean rank**	**median**	**mean rank**
Day 1, air	135	66	178	61
Day 2, argon	15	53	169	49
Day 3, air	26	52	178	57
Day 4, 30% CO_2 in air	15	47	162	45
Day 5, air	30	57	179	58
Day 6, air	15	50	172	51
Day 7, 90% CO_2 in air	3	19	120	27
Day 8, air	65	56	174	47
Day 9, 90% CO_2 in air after 24h fasting	2	10	93	15
Day 10, air	59	58	165	53

Data were subjected to a Kruskal-Wallis test ($H = 40.37$ for time to first withdrawal of head; $H = 26.66$ for the total time spent in the box; $df = 8$).
Chi-square at 5% confidence level = 15.51.

The day after the 90 per cent carbon dioxide treatment, when air was present in the box, two Duroc pigs hesitated to enter the box. In addition, the Large White pig which walked out of the experimental pen during the 90 per cent carbon dioxide treatment would not enter the box voluntarily. However, after moving it back into the experimental pen and providing some physical coercion, it finally entered the box. Neither the time to first withdrawal of the heads nor the total time spent in the box on this control day differed from the previous control days.

Fasting pigs for 24h before subjecting them to the 90 per cent carbon dioxide treatment did not overcome their reluctance to feed in the box. In fact, all the pigs withdrew their heads immediately, one Duroc pig did not re-enter the box after the first attempt and four Large White pigs walked away from the box after their first attempt at entering the box. These pigs were persuaded to stay in the experimental pen and near the box, and with some coercion they made further attempts to enter the box. Pigs which made subsequent attempts (3 to 19) to feed contributed substantially to the total time spent in the box.

On the last control day, four Duroc pigs hesitated to enter the box, but after a few attempts they entered the box and spent a considerable time feeding. Thus, the total time spent in the box improved significantly beyond that of the previous day.

Discussion

This study clearly indicated that, given a free choice, the majority of the pigs (88%) avoided a 90 per cent carbon dioxide atmosphere to accept a reward. This occurred when they were presented with the gas for the first time as well as after fasting them for up to 24h. This aversion was increased during the second exposure to this gas as shown by the trial 2 pigs. Cantieni (1976) also found that pigs showed aversion to carbon dioxide. His experimental pigs stayed deprived of water for 72h rather than endure a second exposure to 70 per cent carbon dioxide in air. However, from Cantieni's work it was not possible to conclude whether the induction of anaesthesia with the carbon dioxide gas or the recovery from the carbon dioxide-induced acidosis was stressful to the pigs. Whereas, the results of the present study indicated that the initial inhalation itself was aversive to the majority of the pigs, and that the aversive effect of carbon dioxide gas was so severe that some pigs (38%) did not want to enter the box and accept a reward on the following day when it contained air.

From the results of trial 1 it was thought that the Duroc pigs, in comparison with the Large White pigs, had more aversion to 90 per cent carbon dioxide. However, the results of trial 2 indicated that this difference was attributable to individual temperament rather than a breed effect. Nevertheless, the conclusion was that the majority of the pigs (88%) demonstrated a degree of reluctance to enter the perspex box containing a high concentration of carbon dioxide. It is very likely that this aversion was due to the pungency of carbon dioxide. This interpretation is supported by the fact that most pigs immediately withdrew their heads from the box. A few pigs which entered the box containing a high concentration of carbon dioxide withdrew their heads only when they began to hyperventilate. In these animals, it is possible that the withdrawal was due to the discomfort caused by the hyperventilation and/or the breathlessness induced by the gas. Human experience also indicated that the discomfort occurring during inhalation of carbon dioxide is due to breathlessness (Gregory *et al* 1990).

Although the subsequent exposures to carbon dioxide which were examined when the pigs were fasted, may have been confounded by their previous unpleasant experience with this gas, the results of this study suggested that the aversive effect overwhelmed the motivation to feed even after a 24h fast.

It appears as though the behaviour of pigs during exposure to 30 per cent carbon dioxide in air produced conflicting results between the two trials. The first trial indicated that the majority of the pigs reacted adversely to the experience of hyperventilation when a low level of carbon dioxide (30% in air) was used because they withdrew their heads. Whereas, the behaviour of the pigs in the second trial indicated that they tolerated a concentration of 30 per cent carbon dioxide in air. This discrepancy may have resulted from the previous exposure of trial 1 pigs to 90 per cent carbon dioxide. It is very likely that those pigs associated the smell of carbon dioxide gas when 30 per cent of this gas was presented in the box, to the unpleasantness they had experienced on the previous occasion with 90 per cent carbon dioxide. On the other hand it is also possible that the trial 2 pigs, in comparison with the trial 1 pigs, were more tolerant to the aversive effects of carbon dioxide as they had spent relatively more time feeding inside the box in the presence of 30 per cent carbon dioxide gas. Nevertheless, it is apparent that the majority of the pigs (overall 75%) did not show any aversion to the presence of 30 per cent carbon dioxide in the box.

By contrast, none of the pigs had any aversion to the presence of argon and in fact they continued their efforts to feed inside the box almost to the point of the onset of unconsciousness. They did not show any discomfort or fear in entering the box again as soon as they regained their posture and did not appear to recall any unpleasant experience associated with the box on the following day. This clearly indicated that the induction of anaesthesia with argon-induced anoxia is smooth, non-aversive and did not impart any sense of breathlessness as otherwise seen with the high concentration of carbon dioxide.

Animal welfare implications

From a welfare standpoint, it appears that using anoxia would be the preferred option for gas stunning pigs. If a mixture of 30 per cent carbon dioxide and 60 per cent argon in air proved to be quicker in comparison with 90 per cent argon in inducing loss of brain function, then this mixture could also be acceptable. The current system of using a high concentration of carbon dioxide for stunning pigs would appear to have some welfare disadvantages.

It is concluded that inhalation of a high concentration of carbon dioxide is aversive to the majority of pigs and, given a free choice, they refused to obtain the reward presented in the carbon dioxide atmosphere even after 24h fasting. By contrast, pigs did not perceive any aversion to the presence of argon and the majority of them did not perceive any aversion to the presence of 30 per cent carbon dioxide in air.

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