The use of Mixtures of the Gases CO2, O2, and N2 for Stunning or Killing Poultry - Report of the Scientific Committee on Animal Health and Animal Welfare adopted 23rd June 1998

The use of mixtures of the gases carbon dioxide, oxygen and nitrogen for stunning or killing poultry

Background

1. The Scientific Veterinary Committee adopted a report on the Slaughter and killing of animals on 30 October 1996 (Ref. VI/1719/97). Methods for stunning and killing all food animal species were considered in that report.

2. In the case of poultry, the Committee considered two methods for gas stunning and killing poultry (Argon 1: >90% argon in air; Argon 2: a mixture of >60% argon and 30% CO2 in air). Insufficient scientific information was available to consider other gas mixtures that could be used for stunning poultry species, although there was some evidence that some methods using carbon dioxide were inadequate. Reference was also made, at that time, to research which was underway into stunning or killing of poultry using mixtures of carbon dioxide, oxygen, and nitrogen.

Request for Opinion

3. The Scientific Committee on Animal Health and Animal Welfare is asked to report on the suitability, from an animal welfare point of view, of the use of mixtures of the gases carbon dioxide, oxygen, and nitrogen for the stunning and killing of poultry.

Methods examined

4. The Committee is aware of 5 methods involving combinations of various gases that are being used in the EU for stunning or killing of poultry, either for commercial or research purposes. However, in many cases there is no published scientific information available and in some cases research is still being carried out and so we have had to rely on work that has not always been peer reviewed in the absence of any other data. All methods involve the use of carbon dioxide at various concentrations which vary because while CO2 is able to stun or kill, it is also irritant, for example, to mucous membranes of the nose and mouth due to the formation of carbonic acid. Consequently, researchers have been seeking an optimum concentration that will stun or kill in a reasonable time without being irritant. The 5 methods are as follows.

- Method 1: 40% CO2 , 30% O2, 30% N2

The effects of exposing broiler chickens to this gas mixture for two minutes have been tested and the results reported at a scientific symposium (see Lambooij, 1997; see also EU-AIR, 1996; Lambooij et al., 1998, submitted for publication; Raj et al. 1998a)

- Method 2: 30% CO2 , 20% O2, 50% air

In this method, birds are exposed to the gas mixture for two minutes. As normal air contains about 21% oxygen the total oxygen content of the gas mixture in Method 2 is roughly the same as in Method 1.

- Method 3: 3 phases of carbon dioxide in air

This process involves exposure to increasing concentrations of carbon dioxide in air at around 20% CO2 for approximately 30 seconds, then 40% CO2 for 50 seconds, and finally 50% CO2 for 30 seconds. This is in commercial use in Germany for the slaughter of broilers.

- Method 4: Method 1 followed by exposure to 80% CO2 in air

This exposes birds to one minute of Method 1 (40% CO_2) followed by two minutes at 80% CO_2 in air (or 80% CO_2, 10% O_2, 10% N_2) and is being used commercially. The principle of this method is to first stun the bird with a non-aversive gas combination and then to kill it while it is still unconscious with CO_2 which otherwise would induce severe irritation and aversion. This is in commercial use in Belgium and has been reported at a scientific symposium (Nieuwelaar & Hoen, 1997).

- Method 5: 45% CO_2, 55% air

This has been investigated as a research method and involves exposure to this gas mixture for more than 2 minutes if the birds are to be killed as opposed to stunned. Some published scientific evidence regarding the effect of exposure of culled layer hens and broilers to this gas mixture is available (Raj et al., 1990).

Stunning vs Killing

5. An important distinction between the methods is whether they stun or kill. Stunning methods are those which are reversible and where the animal will recover if it is not exsanguinated or otherwise killed after leaving the gas mixture. Killing methods, on the other hand, will guarantee that the animal will be dead at the end of the exposure.

6. When stunning methods are used, the stunned animal is killed by another method, usually by exsanguination after severing the carotid arteries and jugular veins. It is, therefore, essential that the killing should be completed ie. the animal should have been sufficiently bled out so that it never regains consciousness. Ideally both carotids and jugulars should be severed by the neck cut. However, in commercial poultry slaughter plants this does not usually occur as the cut is made on only one side of the neck by the automatic killer. Furthermore, in birds bled manually, like turkeys, both carotids are not regularly severed. Consequently, killing methods may be preferable as they ensure that birds do not regain consciousness, whereas with stunning methods the speed and duration of stunning in practical situations must be carefully evaluated and shown to be effective.

7. In respect of stunning, poultry present particular difficulties in that their respiratory physiology is such that they recover remarkably rapidly from many methods of gas stunning. For example, research has shown that broilers surviving two minutes in 45% CO_2 responded to comb pinch as early as 26 seconds after stunning, while broilers surviving argon anoxia responded as early as 15 seconds after exposure (Raj & Gregory, 1990).

8. A practical problem when stunning of poultry is desired, is that a proportion of birds actually die within the exposure time required to stun all birds effectively (eg. with gas mixtures containing 30% or more of CO_2). This has to be taken into account where religious requirements demand reversible stunning.

Handling of Birds prior to Slaughter

9. Under the existing system of stunning by electrocution, it is necessary that birds be unloaded from the crates and hung upside down on shackles prior to stunning. The opportunity to avoid this procedure through the use of gas methods has obvious welfare benefits. Normally, in gas stunning or gas killing systems, poultry are transported to the slaughterhouse in crates which can be placed directly into the gas mixture. Therefore, one great advantage of using gas mixtures is that a minimum of handling is required with no need for additional handling of the birds (eg. hanging and shackling) necessary with the use of many other methods. Some handling of birds when they arrive at the slaughterhouse is unavoidable as meat hygiene regulations require that birds that arrive dead are separated. (Council Directive 71/118/EEC Annex I, Chapter VI, paragraph 33)

10. It is important when using gas methods to ensure that all birds are placed in the gas properly so they are rapidly exposed to the correct mixture. Therefore, measures need to be taken to ensure that birds are evenly spaced on a conveyor or, in the case of crates, are prevented from climbing on top of each other while entering the chamber. In addition the design of the crate should be such that gas exposure is not hindered.

11. As some birds may not inhale a sufficient quantity of the mixture because of air trapped between clustered or

bunched birds in crates or conveyors, and also because of biological variation in susceptibility to the effects of the gas, a small proportion of birds may not be stunned effectively. It is therefore essential, that slaughterhouses maintain a back-up system to kill birds which show signs of recovery after leaving the stunning unit or during bleeding.

Carcass Quality and Meat Quality

12. Safety of personnel and some aspects of carcase and meat quality which may not be relevant to animal welfare are nevertheless important factors in commercial acceptance of any method of stunning or killing.

13. We use the term Carcass Quality to refer to the extent of any defects caused by the stunning process, such as muscle haemorrhages or bone fractures; and Meat Quality to refer to aspects such as colour, pH, and texture.

14. Another advantage of gas stunning or gas killing methods, in comparison with electrical stunning, is that they may improve carcass and meat quality. However, gas stunning and gas killing methods that induce a rapid loss of consciousness also result in convulsions (marked wing flapping) which may adversely affect meat quality and cause carcass defects (eg. fractures, haemorrhages), as well as being aesthetically unpleasant (see paragraphs 19 & 51).

15. Some changes in meat quality, such as colour, are noticeable with gas stunning or gas killing methods but these appear to be neither commercially significant nor detrimental eg. colour of some meat cuts and the liver due to residual blood (Uijttenboogaart, 1997). Stunning with CO_2 causes development of rigor after death to be slower, delaying maturation whereas the use of Argon based gas mixtures speeds up this process. This may have both advantages and disadvantages according to the specific meat processing to be employed. In general, argon stunning or killing appears to have additional benefits to the industry compared with other methods.

16. Another aspect of carcase quality is the efficiency of plucking and the resulting appearance of skin. These are related not so much to use of the gas method itself, but are related to transport and lairage conditions, as well as carcass cooling that takes place in the time between the death of the bird and the commencement of scalding, scald water temperature and the efficiency of the pluckers.

Consideration of the suitability of each method

17. There are three important criteria against which any method of stunning should be judged:

- the stunning process itself should not impose undue suffering on the bird;
- the birds should be rendered unconscious and, therefore, insensible to any pain or mental distress that might be caused by subsequent procedures such as neck cutting and bleeding; and
- the birds should remain unconscious and insensible until death occurs.

18. Signs of distress and pain may be indicated by the degree of head-shaking (Zeller et al., 1988; Hoenderken et al., 1994; Erhardt et al., 1996; Raj, 1996a), gasping (Raj and Gregory, 1994), yawning (Erhardt et al., 1996), vocalisation (Zeller et al., 1988), sneezing (Hoenderken et al., 1994) and defecating (Zeller et al., 1988). However, some of these signs may simply reflect physiological responses or varying degrees of distress (see also paragraphs 34 & 50). For example, yawning indicating oxygen starvation; gasping indicating difficulty in breathing; head shaking and sneezing indicating irritation; defecating indicating fear; and so have to be interpreted with caution. It has to be noted that these are not absolute criteria and that quantitative differences may be significant from a welfare point of view, as well as the time at which they occur. Thus with the 60% Argon/30% CO_2 mixture already judged to be acceptable by the Scientific Veterinary Committee, some of these signs occur in some birds at some point in the process.

19. Unconsciousness is a state in which animals will be insensible and so not be able to feel pain or experience mental distress and it is obviously important to determine this state accurately after exposure to gas mixtures or during bleeding. It may be judged in several ways eg. by the absence of Somatosensory Evoked Responses (SERs), by the absence of Visual Evoked Responses (VERs), and by the EEG (theta and delta waves tending to an isoelectric state). Consciousness may be indicated by open eyes with normal sized pupils, or behaviours such as head shaking, gasping for air, wing flapping, vocalisation. Wing flapping was observed before the onset of loss of posture when exposed to

argon or Argon/CO2 gas mixtures (Lambooij & Pieterse, 1997; Lambooij, 1998, personal communication) and may be an attempt to maintain balance and/or a response to anoxia. But marked wing flapping may also be due to convulsions.

20. Whereas a positive response to a painful stimulus provides good evidence that an animal is conscious of pain, a negative response could be indicative of unconsciousness, or it might reflect deep analgesia with birds still being mentally aware. This would be relevant in relation to animals remaining unconscious for an adequate period of time between stunning and exsanguination. Raj and Gregory (1990) reported that 14% of chickens, surviving an exposure to 45% CO2 in air for 2 minutes, failed to respond to comb pinching even after 6 minutes although they had regained consciousness. However, the majority of the 28 surviving birds (24 birds or 86%) responded to comb pinch within 30 seconds indicating a rapid return to a conscious and pain aware state. Consequently, more comprehensive evidence of unconsciousness than simple comb pinching is required and it would also be important to determine both the time that consciousness and sensibility was regained, as well as the proportion of birds in that state.

21. When poultry are to be stunned using gas mixtures whilst they are still in their transport containers or on a conveyor, the time between the end of stunning and neck cutting is likely to be longer than under electrical stunning systems where the birds are already shackled when stunned. Therefore, the feasibility of performing neck cutting and adequate bleeding of birds while they are still unconscious needs to be demonstrated under commercial conditions to avoid poor animal welfare.

22. Death of a bird would be evidenced by a complete cessation of breathing or of heartbeat or by permanent destruction of the central nervous system. In experimental validation trials on any method this might be interpreted as an absence of breathing or normal heart beat, or an isoelectric EEG, for at least 5 minutes.

23. When evaluating any method of gas stunning one might also consider it in the context of either a one or two phase system. In a one phase method, unconsciousness and death would be induced in a non-aversive mixture by an adequate stun time and killing. In a two phase method, unconsciousness would first be induced in a non-aversive mixture, followed by death or an adequate stun time in a gas mixture which could be aversive. If a 3rd phase is thought to be necessary because of occupational safety for humans to prevent excessive spillage of gas from the plumage of the birds as they are removed from the mixture, then its exposure time would be added to phase 2. Any of these ways would be acceptable from an animal welfare viewpoint, but there may be practical difficulties that have to be addressed with any method that requires long time periods in the gas mixture.

24. In order to approve a gas method for stunning or killing poultry in slaughterhouses the following information, based on sound scientific evidence, is likely to be required for each gas mixture and for each species.

- The aversiveness of the method eg. through observations of behaviour, hormonal perturbances.
- The exposure times required to stun or kill effectively, based on evidence of unconsciousness or death.
- The appropriate neck cutting intervals from the end of the gas treatment which will avoid recovery of consciousness either before neck cutting or during bleeding.
- The effects on carcase and meat quality so that the gas mixtures are acceptable to the industry.
- The effects on workers' safety.
- The practicability of the method.

The application of Animal Welfare criteria to the above 5 carbon dioxide methods for chickens

- Method 1: 40% CO2 , 30% O2, 30% N2 with an exposure time of 2 minutes

25. This is a method which stuns birds rather than kills them as exposure for two minutes induces unconsciousness but not death (an isoelectric EEG does not occur in this period). More importantly, Raj et al. (1998a) found that 2 out of 15 birds failed to lose SERs within this time period and so a significant proportion of birds might still be conscious at the end of the exposure. Furthermore, there is evidence that birds find 40% CO2 aversive as work by Lambooij and Pieterse (1997) showed that a significant number of birds, almost as soon as they were placed in this gas mixture, shook their heads and started to gasp in an average time of 3 to 7 seconds, long before they lost consciousness as indicated by a loss of posture (EU-AIR, 1996).

26. It is also of concern that Raj et al. (1998a) found that broilers exposed to this gas mixture for two minutes regained consciousness as determined by the return of SERs and a positive response to comb pinching as early as 30 seconds after returning to atmospheric air. It is highly improbable that proper bleeding and killing could be guaranteed in this short time in a slaughterhouse and therefore it is properly a welfare concern.

27. It may be concluded from this research that the exposure period of two minutes is insufficient from an animal welfare point of view. First, the rapid recovery of consciousness (within 30 seconds) means that birds must reach the neck cutter very quickly after leaving the gas mixture (eg. less than 10 seconds) and this may not be practical in a poultry slaughter plant. Secondly, there is evidence that birds find 40% CO2 quite aversive.

28. It is possible that longer periods in 40% CO2 would be satisfactory but it has to be noted that longer periods might cause practical difficulties in the abattoir but in the absence of research on these specific points it is not possible to draw any firm conclusions. Further research is needed to determine the ideal exposure time required to stun all birds effectively, as well as the interval between stun and neck cutting that will avoid recovery of consciousness. It is also necessary to see if the behavioural observations on the aversive nature of the mixture are corroborated through other studies, as well as the relevance of light and heavy gasping which has been noted (EU-AIR, 1996).

- Method 2: 30% CO2 , 20% O2 in air with an exposure time 2 minutes

29. This is considered to be a stunning method but there is no evidence that birds will lose consciousness after only a two minute exposure, nor that the mixture is not irritant and aversive to birds. However, it has to be noted that this gas mixture containing 30%CO2 may be just as aversive as the 30%CO2 in Argon, but it may take too long a time to stun birds and so be impractical in a commercial setting. Consequently, in the absence of this further evidence this method would not be acceptable.

- Method 3: 3 phases 20% CO2 for 30 seconds, 40% CO2 for 50 seconds, and 50% CO2 for 30 seconds (approximate times).

30. Under this system, birds are conveyed through three chambers containing increasing levels of CO2. This method has apparently been in use in Germany since October 1997 and has been shown to be a stunning method as birds are able to recover after exposure. The lowest starting concentration of CO2 may not be irritant but will it be sufficient to induce unconsciousness before it goes into the 40% CO2 which is probably aversive? At the end of the 3 stage exposure, birds appear to be unconsciousness as there is no reaction to neck cutting. No scientific evidence is available on this method but anecdotal evidence suggests it is worth investigating.

- Method 4: 40% CO2 , 30% O2, 30% N2 for 1 minute followed by 80% CO2, 10% O2, 10% N2 for 2 minutes

31. In this method, birds on a conveyer are exposed to the initial gas mixture for 1 minute to stun them, followed by 80% CO2 for a further 2 minutes to kill them; birds do not recover if left unbled. This is being used in one commercial slaughter house in Belgium.

32. As mentioned above (paragraph 25) it has been found that times longer than 2 minutes are necessary to induce unconsciousness (as measured by loss of SERs) in 100% of birds exposed to 40% CO2, even if the majority of birds had lost SERs after two minutes (Raj et al., 1998a and personal communication), as that still leaves 13% of birds with evidence that they may be able to feel pain. On the other hand, birds did show a loss of posture in 42 seconds in that they were unable to maintain sitting position, neck tension and fell on their sides or backs, but the proportion of birds in this state was not stated (Nieuwelaar & Hoen, 1997; Lambooij et al. 1998 and personal communication). Such ataxia has been accepted as a behavioural indicator of the onset of unconsciousness and hence insensibility (Raj et al, 1992; Raj & Gregory, 1994).

33. The next step of exposure to 80% CO2 to kill the birds, and which is highly irritant, would not be a welfare concern if there was evidence that 100% of birds were unconscious after one minute in the first gas mixture of 40% CO2. Another concern is that even the initial concentration of 40% carbon dioxide may be aversive for birds (see paragraph 25). Evidence is also needed on the proportion of the birds that are dead after the second period ie. after the 80% CO2.

34. It is worth comparing this 40% CO2 method with the method involving 30% CO2 with >60% Argon in air, already approved by the Scientific Veterinary Committee. The argon mixture is faster to induce unconsciousness as indicated by loss of posture (in an average of 12 seconds compared with 30 seconds in 40% CO2), and it abolishes SERs in ALL chickens within an average time of 19 seconds (Raj et al., 1992; Raj et al. 1998a). While both methods irritate birds (head shaking and gasping being signs of irritancy that were observed), the total number of gasps is greater in 40% CO2 than in the 30% CO2/Argon mixture. Furthermore, birds are likely to be conscious for longer periods in 40% CO2 as on average they take some 15 seconds longer to lose their posture (EU-Air, 1996, Lambooij & Pieterse, 1997).

35. The following points may be concluded. First, there is no evidence that all birds would be unconscious before entering the aversive atmosphere of 80% CO2. Second, there is evidence that the animals found the concentration of 40% CO2 quite aversive. However, it is possible that the period in 40% CO2 might be satisfactory (or even the use of 30% CO2) if it were extended, but it has to be noted that such periods of time might cause practical difficulties in the abattoir. Alternatively, argon could be used in the first stage. In the light of evidence for the aversiveness of 40% CO2 mixtures and the absence of research evidence on other points mentioned above, it is not possible to recommend this method as currently detailed.

- Method 5: 45% CO2 in air

36. This is a method of killing birds if the duration of exposure is longer than 2 minutes. It has been found that SERs were lost in 8 out of 8 culled layer chickens in an average of 30 seconds after exposure (Raj, Gregory & Wotton, 1990) and killed 72% of birds in 2 minutes (Raj & Gregory, 1990).

37. This would be acceptable for a killing method were it not for the fact that 45% CO2 is aversive to the birds and, therefore, it cannot be considered suitable from an animal welfare point of view. It may also have practical drawbacks in the slaughterhouse because of the long time periods likely to be needed.

Day old chicks

38. Three methods are reported as satisfactory for killing day old chicks (Raj and Whittington, 1995). These are:

- exposure to >90% Argon in air until they are dead;
- exposure to 30% CO2 and >60% Argon until they are dead; or
- >90% CO2 in air until they are dead.

The Committee feels that the two methods using argon are likely to be superior. In a previous opinion, the Scientific Veterinary Committee recommended maceration as the preferred method for killing day old chicks.

39. Of the five methods under consideration for adult chickens, none has been tested on young chicks but in view of the resilience of very young birds to carbon dioxide (see Jaksch, 1981 - they appear to have adapted to such conditions during incubation) it is unlikely that any of the methods would be suitable for newly hatched chicks.

Other Species of Poultry

- Turkeys

40. Published information does not exist for methods 1 to 4 for this species, though research is underway on some methods. It has been reported that 50% of turkeys avoided an atmosphere containing 72% CO2 in air (Raj, 1996a). Therefore, Method 5 needs further investigation to evaluate the effects of 45% CO2, especially as 30% CO2 in argon was tolerated well.

41. Considering the recommended methods in the previous report of the Scientific Veterinary Committee (>90 % argon and 30% CO2 in argon), and that hypoxia due to replacing oxygen by argon does not lead to pain or distress in chickens, a prolonged exposure time required to stun or kill turkeys seems acceptable from the animal welfare point of view. The reported results of Raj and Gregory (1994) as well as Raj (1996a) point in this direction but more work is

needed.

- Quail

42. Research is needed in this area. Little is known about the performance of any of the methods under consideration in this species. Two methods which were considered in the earlier report of the Scientific Veterinary Committee have since been investigated in this species: 60% argon and 30% CO2 in air, and >90% argon in air. Both methods killed quails following a two minutes exposure and are considered to be acceptable from a welfare point of view (Tserveni-Gousi, et al, 1998).

- Ducks

43. Ducks, probably because of their aquatic evolution, possess a cardiovascular mechanism which acts to protect the heart and the brain against raised CO2 levels. A further difficulty for gas stunning methods is that a raised CO2 level will cause ducks to go into apnoea. Because of these mechanisms, it can take a very long time to kill ducks with CO2: viz Raj (1996b) found that ducks survived for 7 minutes in 50% CO2 in air, and in view of the concentration of CO2, the mixture could well be aversive.

44. It is unlikely that any of the Methods 1 to 5 would be acceptable on humanitarian grounds for ducks. However, there is evidence that Argon alone or Argon/CO2 mixtures may be used satisfactorily for domestic ducks (Raj et al., 1998b).

- Geese

45. We found no published information on gas stunning or killing of geese.

- Pheasants, Partridge, Guinea Fowl, Pigeons

46. Published information is not available on gas stunning or killing of these birds. However, because they will attempt to fly, it would be important from a welfare point of view for them to be kept in crates during any gas stunning or gas killing procedure.

- Ratites

47. Published information is not available on gas stunning or killing of these birds. However, it should be noted that because of their size, there are likely to be practical problems with the use of gas for stunning and so such methods cannot be recommended.

Research Needs

48. From the scientific evidence available, it would appear that argon has fewer adverse effects than methods involving CO2. It may therefore be more profitable to concentrate on improving the research methods that are based on argon in all species. Nevertheless it is recognised that refinement of CO2 methodology may still produce useful commercial outcomes.

49. None of the newly proposed methods (Methods 1 to 5) has been sufficiently researched on the relevant aspects of animal welfare, carcass quality, meat quality and workers' safety to enable any firm recommendations. From an animal welfare point of view, published scientific data available at present suggests that killing of poultry species, rather than stunning them with gas mixtures, might be preferred or might even be essential to prevent premature recovery. Nevertheless, research is needed into what gas mixtures should be considered for stunning poultry species for commercial reasons. These problems are likely to be further confounded by species to species variation in terms of susceptibility or resistance, the degree to which they are found to be aversive, and the time it takes to render birds unconscious and insensible, any of which may render a gas mixture unacceptable.

50. Another aspect that needs to be investigated is whether, during carbon dioxide stunning, the observed reactions indicating stress such as head shaking (Zeller et al., 1988; Hoenderken et al., 1994; Erhardt et al., 1996; Raj, 1996a), gasping for air (Raj & Gregory, 1994), yawning (Erhardt et al., 1996), vocalisation (Zeller et al., 1988), sneezing (Hoenderken et al., 1994), and defecating (Zeller et al., 1988) are genuine causes for concern.

51. Convulsions (marked wing flapping) have been reported to occur to a greater or lesser degree with most methods but appear to be less severe with gas combinations that incorporate oxygen (Woolley and Gentle, 1988; Raj et al., 1991; Hoenderken et al., 1994). However, they also occur in animals that are unconscious during anoxia (Dell et al., 1961; Ernstring, 1965; Raj et al., 1991). Consequently, it is necessary to have reassurance of a clear point at which birds are unaware of any convulsion that might occur.

Summary and Conclusions

52. The inevitable stress of uncrating and shackling conscious birds under the conventional electrical water bath stunning systems is a welfare concern and the use of gas mixtures for stunning or killing birds can eliminate these stresses.

53. In order to approve a gas method for stunning or killing poultry in slaughterhouses the following information, based on sound scientific evidence is likely to be required for each gas mixture and for each species.

- The aversiveness of the method eg. through observations of behaviour, hormonal disturbances.
- The exposure times required to stun or kill effectively, based on evidence of unconsciousness or death.
- The appropriate neck cutting intervals which will avoid recovery of consciousness either before neck cutting or during bleeding.
- The effects on carcase and meat quality so that the gas mixtures are acceptable to the industry.
- The effects on workers' safety.
- The practicability of the method.

54. Methods using >90% Argon appear best from a welfare point of view

55. Whenever concentrations of CO2 sufficient to stun or to kill birds have been used, there has been evidence of irritation. Low concentrations which may not be irritant may not be sufficient to cause loss of consciousness and insensibility in a time that is practicable.

56. There are a number of important physiological differences between poultry species. Therefore gas mixtures may have to be tailored for each species. Firm recommendations cannot be made at present for the different gas mixtures in the different poultry species, because insufficient research has been performed on either welfare alone, or welfare combined with meat quality aspects.

57. However, a modified version of the 2 step Method 4 exposure to 40% CO2, 30% O2, 30% N2 followed by 80% CO2 in air looks promising for broilers and could be recommended if exposure to an appropriate mixture is sufficient to render 100% of the birds unconscious before entering the 80% CO2 mixture. It also needs to be shown that the combination of 40% CO2 and other gases is not unduly aversive and does not cause irritation to the birds. Method 4 may be acceptable if the gas mixtures or times are changed but further research is needed before this method can be recommended. Method 3, exposure to increasing concentrations of CO2, could be acceptable but again further research is needed before this method can be accepted as humane.

58. The Committee recommends that only >60% Argon and 30% CO2 in air and >90% Argon in air be accepted as humane methods for killing ducks and quails at the present time.

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