Opinion on the Use of High Expansion Nitrogen Foam Delivery Systems for depopulation of poultry flocks affected by notifiable disease in the UK

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The Animal Welfare Committee (AWC) is an independent expert committee of the Department for Environment, Food and Rural Affairs, the Scottish Government and the Welsh Government. Information about the Committee may be found at: https://www.gov.uk/government/groups/animal-welfare-committee-awc

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Introduction and scope

1. The Animal Welfare Committee (AWC) is an independent expert committee of the Department for Environment, Food and Rural Affairs, the Scottish Government and the Welsh Government. AWC Opinions are short reports to Governments on a wide range of contemporary topics relating to animal welfare. They offer authoritative advice, which is based on scientific research, stakeholder consultation and experience. They may highlight particular concerns and indicate issues for further consideration.

2. There are a range of culling methods that the Animal and Plant Health Agency (APHA) and their contractors are using to humanely kill birds on infected premises and in other circumstances. Mechanical percussive devices may be suitable for small flocks, while containerised gassing units (CGUs) and whole house gassing (WHG) are being used on larger premises. Capacity for carbon dioxide (CO_2) based WHG has increased significantly, and it is currently the method of choice where it can be effectively and quickly deployed.

3. There are, however, scenarios where WHG might not be an effective option, e.g. where houses are not able to be fully sealed or if there are challenges to the supply of carbon dioxide.

4. Using high expansion Nitrogen foam has the potential to enhance the government's ability to carry out rapid mass depopulation in Avian Influenza (AI)-infected premises (and other notifiable avian disease situations), providing an additional culling method suitable for naturally ventilated poultry buildings where WHG cannot be used. There may also be advantages to this method in terms of nitrogen being less aversive than CO_2, not requiring the birds to be caught live, gas containment, cost, gas availability and safety around the gas operation.

5. APHA would like to progress its use of this method, through contractors, in a structured way following good practice and in keeping with AWC recommendations, as soon as possible. The aim is to have high expansion Nitrogen foam available for use as an additional technique for mass depopulation as early as winter 2023/24.

6. AWC has been asked to provide an animal welfare assessment of high expansion Nitrogen foam as a method of depopulation for intensively kept poultry, including in comparison to other legal stunning methods, and lead best practice.

7. AWC's opinion was sought on whether high expansion Nitrogen foam is appropriate for mass depopulation of poultry and, if so, how to progress its use as a culling method in AI and other notifiable avian disease outbreaks. The following were considered as part of this review:

- Specific hazards related to high expansion foam as a delivery mechanism for Nitrogen. Notably, behavioural factors on deployment of the foam and that poultry are submerged in foam for a considerable time and not visible for inspection during the killing process. Advice was requested on appropriate monitoring of this method for effective stunning in compliance with Article 5 of retained Regulation 1099/2009 on the protection of animals at the time of killing (PATOK) 'checks on stunning'. Differentiation between different poultry species in the effective use of this method was considered important in this regard.

- Whether further research under experimental protocols with live birds in commercial sheds is necessary before APHA use high expansion Nitrogen foam for all commercial poultry.
- If high expansion Nitrogen foam, as proposed by Livetec Ltd, can be used outside of experimental protocols then how to progress the use of this method on live birds by APHA, including with different poultry species and in different types of poultry environment, e.g. floor, multi-tier and colony cages.
- The welfare advantages and disadvantages of high expansion Nitrogen foam compared to the alternative methods available (WHG and CGUs) that would assist APHA's decision-making process on which systems to deploy if WHG, CGUs and high expansion Nitrogen foam are available.
- Ethical issues around the potential use of high expansion Nitrogen foam in infected commercial poultry flocks.

8. This advice extends to the following poultry species which might be depopulated as part of a mass rapid culling in the UK: chicken (meat and layers), turkey, ducks, geese and game birds.

Legal context

9. AWC is aware of uncertainty around high expansion Nitrogen foam as a novel or accepted method of stunning/killing: the foam acts as a delivery mechanism for Nitrogen, an inert gas, which excludes available Oxygen. The European Food Safety Authority (EFSA) is due to provide an opinion on high expansion Nitrogen foam stunning for pigs and poultry. AWC has noted that difficulties in monitoring birds submerged in the foam may mean that there needs to be consideration by Governments of a derogation from some of the requirements to monitor stunning.

Practical application of mass culling methods

10. Mass killing of poultry requires culling methods which can be rapidly and practically deployed whilst avoiding all unnecessary pain, suffering and distress to the flock being culled out, and also being mindful of human health and safety during the process.

11. Mass killing may be required for culling of flocks suffering from, or contaminated with, notifiable infectious disease, those considered to be dangerous contacts, or those killed promptly as "slaughter on suspicion" after veterinary assessment, to prevent or reduce the spread of significant infectious disease. For poultry, this predominantly applies in respect of Avian influenza or Newcastle disease.

12. Other flocks may need to be subject to on-farm killing in situ due to:
- food safety requirements e.g. contaminated with a regulated Salmonella serovar, or rarely detection of toxins or heavy metal contamination preventing processing through a slaughterhouse;
- damage to buildings due to storm, flood or fire damage making personnel entry for manual live catching and transport unsafe;

- breakdowns or other major events at slaughterhouse limiting capacity and ability to catch and slaughter birds that have reached killing age and maximum stocking density.

13. The various available methods for on farm killing, which are compliant with welfare at killing regulations, include mechanical percussive devices suitable for small flocks, CGUs and WHG for larger flocks and premises. The choice of method deployed depends on a number of variables, including:

- welfare credentials of the method
- zoonotic potential of reason for cull
- clinical state of birds (may be severely sick and moribund with AI, asymptomatic with salmonella or other conditions)
- size of flock
- number of houses on site
- poultry species
- age of birds (chicks, meat birds up to slaughter weight, breeders or layers)
- production system – housed, free range, controlled environment (closed system), open naturally ventilated pole barns, etc.
- housing type and condition (state of repair, leaky or airtight)
- house furniture/equipment, cages, nest boxes, etc.
- presence of electrical equipment
- environment around housing, quality/size of curtilage and integrity of concrete apron for killing equipment and vehicles
- logistics of availability of killing equipment
- logistics of availability of gas (and cost)
- logistics of availability of personnel for deployment of catching or culling method
- logistics of carcase removal with wetness of carcasses, slippery surfaces, etc.

Use of foam in killing poultry

14. Application of foam has been considered for some time as a method of killing for poultry. Foam is generated by specialized equipment using a mixture of water, commercial foam concentrate (originally developed for firefighting), and atmospheric air or a specific gas. Foam is described by its expansion ratio, which is the ratio of volume of foam formed to the volume of solution used to generate it. Low, medium and high expansion foams have expansion ratios of 2-20:1, 20-250:1 and >250:1 respectively.

15. Low-medium expansion air filled foam has been used in the USA and has been shown to be a reliable method of killing (e.g. Dawson et al. 2006[1]). This type of foam has small diameter bubbles and high density. It is applied such that it flows over the birds in their production housing causing death by hypoxia (Benson et al., 2007[2]). Post-mortem examination of birds culled using low-medium expansion foams

[1] Dawson MD, Benson ER, Malone GW, Alphin RL, Estevez I and Van Wicklen GL (2006) Evaluation of foam-based mass depopulation methodology for floor-reared meat-type poultry operations. *Applied Engineering in Agriculture* 22(5): 787-793.

[2] Benson ER, Alphin RL, Dawson MD, Malone GW (2009) Use of water-based foam to depopulate ducks and other species. *Poultry Science* 88(5): 904-910.

indicate that these occlude the airway[3]. Welfare concerns arise from this mode of action which is equivalent to drowning or suffocation (technically defined as physical separation of the upper respiratory tract from atmospheric air), neither of which are recognised as humane under European legislation nor the 2018 World Organisation for Animal Health (WOAH) guidelines on the killing of animals for disease control purposes[4].

16. An alternative is to create high expansion foam (expansion ratio > 250:1) filled with gas, with the intention of using foam essentially as a gas delivery system. In this case, once birds are submerged, a respirable pocket of gas is produced by destruction of foam in the immediate area around the bird, Oxygen is excluded causing rapid loss of consciousness and birds die from anoxia. From the point of view of bird welfare, it enables the use of non-aversive inert gases such as Nitrogen (which cannot be used for whole house gassing because it is not possible to eliminate the Oxygen) and birds not yet submerged are unaffected, unlike with WHG where there will be respiratory responses (e.g. hyperventilation) and aversion as concentrations rise progressively.

17. Delivery of Nitrogen gas in high expansion foam has several potential practical and welfare advantages. It can be applied for whole flock treatment with no need to seal the house, meaning that houses that cannot be adequately sealed and open sided houses can be treated, possibly with some form of netting to contain the foam. Netted areas in gamebird release pens could also be filled with foam. There is also no need to catch and remove live birds from the house, reducing handling stress and significant exposure of personnel to potential zoonotic pathogens (e.g. avian influenza virus, and to a lesser extent salmonella). It reduces demand on carbon dioxide gas (used in WHG) which may be in short supply in the event of a large outbreak.

18. Potential practical issues include the height or volume capacity of houses. Deep pit laying houses may require increased volume of foam or require preparation to close off the pit area before deploying foam. Houses with multi-tier cages or multi-tier barn systems with multiple levels and nest boxes present issues with height of foam needed to cover birds at higher levels or such equipment disrupting flow of foam or loss of integrity of foam bubbles reducing efficacy of distribution. These housing systems may, at this stage, be more suited to WHG. Broiler breeder, layer breeder and duck breeder flocks may be housed on one level, but part of the floor area may be occupied by raised slatted areas and/or nest boxes. One trial (see paragraph 32 below) showed that the foam ‘wall’ could overcome these obstacles.

19. Floor based systems on litter on one level appear to offer the optimal house profile for foam flow and distribution, meaning that the technique would be most efficient for litter-based broilers, broiler breeders, meat turkeys and meat ducks. Consideration must be given to potential for avoidance of high expansion foam flow by birds walking away from the approaching foam “wall” – work to date on behaviour suggests that broilers are unlikely to move away from foam, especially after the brooding phase. Turkeys and ducks may be expected to remain more mobile in the

[3] Benson ER, Alphin RL, Dawson MD, Malone GW (2009) Use of water-based foam to depopulate ducks and other species. *Poultry Science* 88(5): 904-910.

[4] https://www.woah.org/fileadmin/Home/eng/Health_standards/tahc/2018/en_chapitre_aw_killing.htm

house, but experimental work[5] suggests they show no specific aversion, panic or concern. With market age turkeys the limiting factor may be height of foam to ensure full and prompt immersion of heads when in standing position, although foam height in trials was significantly higher than this.

20. There is a requirement to seal any electrical equipment in the house prior to deployment of wet high expansion foam which will require some personnel entry into house and time to set up.

21. Other practical issues include the physical ability to deploy the necessary equipment on site adjacent to poultry houses. This may be affected by the quality/size of curtilage and integrity of the concrete apron or hard standing at house entrances, especially in inclement winter weather.

22. Logistical limitations include the availability of specialised equipment, its rapid deployment and cleansing and disinfection between sites, power and water source sufficient to run equipment, the availability of Nitrogen gas and adequate, trained personnel for deployment of technique or catching.

23. Although outside AWC's remit, there are potential environmental impacts to consider in the use of high expansion Nitrogen foam, including the diesel in several vehicles used to transport resources and generate the foam; the environmental impact of the foam covering the area, i.e. how biodegradable the foam is and how long it would take to degrade; chemicals used in dispersal of foam and disposal of the birds by incineration or burial.

24. On removal of carcases after culling some potential practical issues exist:

- Is it possible to include disinfectant in the high expansion foam to dampen down any infectious virus? What effect might this have on surfactants?
- How quickly does high expansion foam disperse to allow personnel entry to remove carcases?
- How "wet" will carcases be? Impact on handling and rate of decomposition depending on ambient temperature.
- Can wet litter be disposed of in a biosecure way?

Research

25. There has been limited field-based research on the humaneness and effectiveness of high expansion Nitrogen foam as a mass killing method for poultry. Much of the research to date has focused on demonstration of proof of principle and humaneness in controlled laboratory conditions.

26. Early experiments established that high expansion foam (expansion ratio 300:1) was able to contain and deliver CO_2 to layer hens (n=6). In this study birds were able to be rapidly immersed in CO_2 foam within 20 seconds, displaying increased alertness during the initial onset of foam introduction but minimal reported

5 Physiological and behavioral responses of poultry exposed to gas-filled high expansion foam. D E F McKeegan [1], H G M Reimert, V A Hindle, P Boulcott, J M Sparrey, C M Wathes, T G M Demmers, M A Gerritzen. Poultry Sci 2013 May;92(5):1145-54

fear behaviours[6]. There were behavioural signs associated with high levels of CO_2 and there were no traces of foam in the respiratory tract or lungs.

27. A similar pilot study examined the use of Nitrogen (N_2) filled high expansion 'dry foam'. This reported that layer hens exposed to high expansion foam which contained atmospheric air (n=5) remained alive during the entire recording period, while those exposed to high expansion N_2 foam (n=5) died rapidly (within seconds). Although small quantities of pinhead-sized bubbles were seen in the upper respiratory tract (larynx), these were insufficient to cause obstruction of the trachea[7].

28. Laboratory based experiments examined the electrophysiological and behavioural responses of poultry to either CO_2 (broilers, ducks and turkeys) or N_2 (layer hens and broilers) filled high expansion foam (expansion rate of 300:1)[8]. Like previous studies, there was minimal aversion to the initial introduction of the foam. Based on electroencephalographic (EEG) indices of consciousness/unconsciousness, all species became rapidly unconscious after submergence in the foam, with N_2 filled foam inducing undoubted unconsciousness within a mean of 30 ± 2 and 18 ± 1 seconds in layer hens and broilers respectively. After submersion, birds displayed ataxia, loss of posture and vigorous wing flapping which are characteristic of anoxic death. Monitoring showed that the O_2 levels inside the N_2 foam were less than 0.5%. Birds submerged in CO_2 filled foam in the same study became unconscious within 16 ± 1, 1 ± 1 and 15 ± 1 seconds in broilers, ducks and turkeys respectively. Birds exposed to CO_2 filled foam displayed gasping and increased headshaking prior to loss of consciousness, potentially indicative of respiratory distress and aversion. Pre-submersion exposure to CO_2, which collected in the bottom of the vessel used to apply the foam to birds, also explains the short latencies to loss of consciousness. This did not happen with N_2 foam application, due to lower gas density.

29. Larger group laboratory trials (n=95 broilers, stocking density of 34kg/m^2), found that during application of high expansion foam from above, wing flapping could result in substantial destruction of the foam matrix, which could interfere with maintenance of the anoxic envelope around birds[9]. This work highlighted that the delivery rate of foam must exceed the destruction rate from flapping and that a minimal foam height above the birds must be maintained during bouts of wing flapping.

30. Subsequent trials with broilers designed to simulate near commercial conditions and stocking densities reported that with multiple foam generators positioned equally across the width of a pen, a horizontally moving bow wave spanning the whole width of a pen could be created with sufficient depth to continue

[6] Gerritzen MA and Sparrey J (2008). A pilot study to assess whether high expansion CO2-enriched foam is acceptable for on-farm emergency killing of poultry. *Animal Welfare* 17: 285-288.

[7] Raj ABM, Smith C and Hickman G (2008). Novel method for killing poultry in houses with dry foam created using nitrogen. *The Veterinary Record* 162: 722-723.

[8] McKeegan DEF, Reimert HGM, Hindle VA, Boulcott P, Sparrey JM, Wathes CM, Demmers TGM, and Gerritzen MA (2013). Physiological and behavioral responses of poultry exposed to gas-filled high expansion foam. *Poultry Science*, 92(5), 1145-1154.

[9] MH0143 (2008). Welfare assessment of anoxic gas-foam as an agent for emergency killing of poultry. Defra final report. https://randd.defra.gov.uk/ProjectDetails?ProjectId=15445

to cover birds during bouts of wing flapping[10]. In these trials patterns of behavioural and EEG activity closely matched those in single bird laboratory trials, with birds becoming undoubtedly unconscious between 14.4 to 30.9 seconds after submergence in the foam. In these group trials there was aversion to the advancing foam front, consisting of birds walking away and some cases of vigorous wing flapping/jumping when contacting the foam. Birds also accumulated at the end of the pen, which could lead to smothering at commercial scales, particularly with layer hens. It was hypothesised that these reactions may be due to the visual impact of the advancing foam in lit conditions and may be ameliorated by use of low lighting.

Field trials

31. In March 2023, Livetec Ltd demonstrated to APHA and members of the committee a high expansion Nitrogen foam delivery system (high expansion Nitrogen foam) in an empty broiler shed. There is at least one other company that is making similar technology available (Heft International[11]). Therefore, high expansion Nitrogen foam could soon be an available option that APHA could use for mass depopulation of poultry affected with notifiable avian disease.

Field trial of high expansion Nitrogen Foam, November 2023

32. Livetec were commissioned by APHA to demonstrate generating high expansion Nitrogen foam first in an empty house and then in a house containing live broiler breeders, under commercial field conditions. Members of AWC witnessed this demonstration. Livetec provided all the equipment and staff needed including multiple remote cameras in the houses to monitor the progress and distribution of the generated foam and the behaviour of the birds.

33. The empty house trial confirmed that a wall of foam over 1 metre tall could be generated quickly, effectively maintained across the house and distributed along the littered floor area and up and over the slatted area and nest boxes. The foam wall was seen to move forward rapidly and maintain its integrity across the section of the house being filmed.

34. When complete, staff entered wearing breathing apparatus to spray foam with dispersant (10% alcohol in water). Foam height rapidly reduced although leaving a patchy layer of up to 10cm on the litter and slats. Leaf blowers were used to disperse the foam further to see the floor. Entering the house after the nitrogen was vented showed litter to be damp rather than wet with no evidence of run off outside the house. Raised slats were slippery due to foam and dispersant.

35. For the trial on the house containing live birds, two foam generators were placed on the litter areas at each end of the house. Initially two generators at one end were set to produce a foam wall moving slowly down the house with cameras monitoring bird behaviour. Fans and lights were turned off and infrared cameras used. The foam wall generated well, and height was maintained well above bird height.

[10] MH0144 (2010). Further Study to Develop a Humane method to Kill Poultry Using Gas Filled Foam. DEFRA final report. https://randd.defra.gov.uk/ProjectDetails?ProjectId=16822

[11] Technology - Heft International

36. There was no evidence of panic behaviour or excessive surging in advance of the foam wall, birds reacting mildly to feeling the foam approach. Some birds walked back into the foam wall. There was some bunching of birds at the edge of the foam, mostly appearing as a reaction to the birds engulfed by the foam flapping.

37. The bird height camera showed birds dropping rapidly as engulfed by the foam. Some agitation of the foam bank was seen in reaction to bird flapping, but no birds were seen above the foam. Agitation ceased quickly. As the trial progressed Livetec swapped to the two foam generators at the far end of the house to produce a foam wall from that end. The birds waiting for the second wall were quiet and showed no distress as the two walls met and merged.

38. After a suitable dwell time, staff wearing breathing apparatus entered the house to spray foam dispersant, combined with switching on the ventilation and using leaf blowers to disperse foam further and vent nitrogen. Nearly all the birds had died on their backs and were well distributed throughout the house with no evidence of smothers or bunching. Most carcases were on the littered floor area with around 10% dying on the slatted areas.

39. Overall, the camera footage appeared to show no excessive bird activity or distress with birds outside the foam wall remaining quiet and “normal”. As the foam moved over the birds it was no longer possible to visualise birds as they died, other than the bird height camera which appeared to show birds becoming recumbent as soon as the foam covered them. There was no evidence of any surviving birds.

40. In summary the process was technically well delivered with the foam wall generated at a height capable of submerging all birds with all being killed rapidly.

Animal welfare assessment

41. There are welfare benefits in using high expansion foams compared to low-mid expansion foams. Low and mid expansion foams have small-mid diameter bubbles and high density that can lead foam to occlude the airway and kill birds by asphyxiation, and as a result should not be used for culling poultry. As described above (see paragraph 27), high expansion foams do not appear to occlude the airway and thus do not cause death by asphyxiation. Instead, unconsciousness is caused by cerebral hypoxia prior to death by anoxia.

42. Once birds are immersed in high expansion Nitrogen foam, the destruction of the foam bubbles immediately around the animal produces a localised pocket of Nitrogen that completely excludes Oxygen from around the bird. Post-mortem examinations indicate that the airway is not occluded by the high expansion Nitrogen foam (confirmed by the live trial AWC witnessed in November 2023) and behavioural assessment suggests that these birds do not show respiratory distress and aversion prior to death. Instead, electroencephalographic (EEG) brain wave patterns, ataxia and wind flapping indicate that both broiler chickens and layer hens rapidly become unconscious (well within 60 seconds) after being submerged in the foam, indeed, in shorter times than seen in comparable slaughter systems. Even with a relatively high stocking density, the Nitrogen foam still delivered a "reliable and humane anoxic" kill. OBJ

43. Unconsciousness is caused by cerebral hypoxia prior to death by anoxia, which is rapid. The anoxic impact of high expansion Nitrogen foam should work physiologically in a similar way for all poultry and thus provide an effective kill for contained birds. Although, practical difficulties exist in monitoring Oxygen levels/displacement in the house and observing birds during the process to monitor their response, behavioural signs of pain or distress and time to unconsciousness/death (white birds in opaque white foam), these are being overcome. Much can be extrapolated from previous research on individual bird/species responses and times to loss of consciousness (data suggests it is more rapid than other methods of culling), but some practical approaches are needed to assess a whole flock response and to be legislatively compliant. Evidence is still required on possible differential behavioural responses to the foam delivery system depending on bird age or poultry species/type.

44. Research suggests that high expansion Nitrogen foam for whole flock depopulation may have several potential welfare advantages that recommend it as an effective method for culling poultry. Research studies using broiler chickens and hens have shown proof of principle. However, it should be noted that there have been only a few field-based research studies undertaken to date and these have been limited to floor-based systems containing broiler chickens and broiler breeders.

45. Without further trials to determine whether high expansion Nitrogen foam penetrates cages efficiently and effectively or provides sufficient foam coverage for multi-tier housing systems, it is not currently possible to assume that birds housed in tiered colony cage systems or multi-tier barn systems would experience the same welfare outcomes. Nor is it possible to extrapolate all the behavioural findings to all other species or ages of bird, especially younger birds and game birds that may be more mobile. Some geese and ducks may display resistance to hypoxia that could make their time to death longer.

46. Welfare benefits in floor-based housing systems include the ability to apply high expansion Nitrogen foam to a house without needing to catch and handle live birds, thus removing any concerns regarding handling stress. Obviously, this benefit is lost if the Nitrogen foam is used in combination with systems that require the birds to be caught, handled and placed in a container prior to the Nitrogen foam being deployed.

47. It has been reported that there is a mild aversive response to the advancing foam front, with birds walking away or in some cases vigorous wing flapping/jumping when contacting the foam[12]. Whilst this response was considered an avoidance reaction to the foam, the researchers did not consider that the birds were panicked by its presence. However, the consequence was that birds accumulated at the end of the pen, and a few jumped on others.

48. It is possible that chickens may have responded in this manner due to the visual impact of the advancing foam and it has been suggested that this could perhaps be ameliorated by use of low lighting. Subsequent work reported to AWC by Livetec Ltd has suggested that foam generators placed at both ends of a house

[12] MH0144 (2010). Further Study to Develop a Humane method to Kill Poultry Using Gas Filled Foam. DEFRA final report. https://randd.defra.gov.uk/ProjectDetails?ProjectId=16822

stops the birds accumulating at one end. Recent field trials using broiler breeders observed by members of AWC (see paragraphs 32-40) showed that combining low lighting with placing foam generators at both ends of a house reduced the likelihood of birds getting smothered by others prior to immersion in the foam.

49. Behaviour of sick and dying birds may vary from healthy birds in reacting to the foam. There could be less bird movement to avoid interactions with healthy birds or release gas from the foam, although gas filled foam would anyway displace available Oxygen.

50. High expansion Nitrogen foam production and flow was unintentionally interrupted during one of the trials performed in a Defra-funded 2010 study[13]. This resulted in some of the birds that had been submerged being re-exposed to the atmosphere. This was considered to be distressing for any conscious birds. If during filling of the house, foam fails to cover the whole shed, birds on the periphery of the foam presumably may be adversely affected by being partially submerged or intermittently exposed to anoxic conditions. Accessing birds caught in between two approaching walls of foam may also be challenging. However, as discussed above (see paragraph 47) birds that have not yet been completely submerged are unaffected by the Nitrogen gas, limiting the welfare impact of this type of technical failure. Birds under the foam will be exposed to significant anoxia which results in very rapid loss of consciousness. Despite this, procedures need to be in place to ensure that similar technical failures should not happen once foam release starts, and that foam wave height is high enough to overtop all birds, including when foam starts to break down and release gas.

51. A further welfare concern is the possibility of eye and skin irritation from the foam constituents. However, the lack of an "irritant" behavioural response in studies of broilers and laying hens would perhaps suggest that these particular types of bird are not sensitive to the foam formulation used in that specific study[14]. Birds were submerged in air filled foam and stood quietly without signs of irritation until retrieved.

52. A benefit of high expansion Nitrogen foam when compared to Whole House Gassing (WHG) with CO_2 is that with the former birds are unaffected by the gas until they are submerged in the foam where hypoxia will develop. In contrast, in WHG, birds are exposed to progressively higher CO_2 levels, although they should be unconscious before exposure levels considered aversive (>20%). Studies have demonstrated that exposure to high levels of CO_2 is noxious to birds and gas mixtures containing CO_2 also induce signs of hyperventilation before loss of consciousness (reviewed in [15]). There is a risk of respiratory distress. These risks should be assessed against the harms caused by infection with high pathogenic

[13] MH0144 (2010). Further Study to Develop a Humane method to Kill Poultry Using Gas Filled Foam. DEFRA final report. https://randd.defra.gov.uk/ProjectDetails?ProjectId=16822

14 McKeegan DEF, Reimert HGM, Hindle VA, Boulcott P, Sparrey JM, Wathes CM, Demmers TGM, and Gerritzen MA (2013). Physiological and behavioral responses of poultry exposed to gas-filled high expansion foam. *Poultry Science*, 92(5), 1145-1154.

[15] McKeegan, D (2018) Mass Depopulation In Advances in Poultry Welfare; Elsevier, pp 351–372. https://doi.org/10.1016/B978-0- 08-100915-4.00017-8

avian influenza (see AWC advice on poultry culling for depopulation – consideration of ventilation shutdown, paragraphs 30-31[16]).

Ethical analysis

53. In line with its previous work and Opinions, the ethical approach which AWC has adopted in considering this issue is a primarily utilitarian one in which the human use of animals is considered permissible to achieve important benefits, providing that animal welfare is safeguarded as far as possible and, as a minimum, in accordance with national and, where relevant, international legislation. The utilitarian approach adopted by AWC is qualified in that the justification of harms is considered in relation to both the magnitude and importance of the benefits that accrue, within the context and situation under consideration. AWC recognises that there are some harms which, due to their severity, should not be inflicted upon animals under normal circumstances. Animal welfare should be maximised as far as possible in each and every situation to ensure that animals have 'lives worth living' and ideally 'good lives'[17].

54. Whenever any animal is killed or slaughtered, this should be performed in a humane manner that minimises pain, distress and suffering at all times during the process. During depopulation for disease control, the need to protect animal welfare must be balanced against the need to protect the health of workers, public health, and the need to control the spread of disease to other poultry and wildlife. The ethical approach described above dictates that the method which is least harmful to the poultry involved should be used, whilst allowing for adequate and necessary protections of those humans working to depopulate housing for disease control, public health, other poultry, wildlife and the environment.

55. The use of high expansion Nitrogen foam can offer reduced harms to poultry compared to other methods of depopulation. However, work on overcoming logistical challenges around its use, e.g. difficulties in directly observing the welfare of birds that are submerged in the foam, is still on-going. It is not currently possible to say with certainty whether the use of high expansion Nitrogen foam is preferable on welfare grounds to the use of WHG using CO_2. This is because the true aversive experience for birds when exposed to levels of CO_2 in the initial phase of WHG before unconsciousness intervenes is currently unclear. Furthermore, the welfare impacts of the use of many methods of depopulation, including high expansion Nitrogen foam, vary with the specific circumstances of the management system and poultry involved.

56. The preceding sections of this report indicate that when compared to other methods of effective depopulation of poultry for disease control, high expansion Nitrogen foam offers additional benefits to humans as it reduces significant exposure of personnel to potential zoonotic pathogens. The fact that workers do not have to handle live poultry directly to depopulate the housing may also reduce adverse psychological effects on humans.

[16] Animal Welfare Committee: advice on emergency culling for the depopulation of poultry affected by high pathogenic avian influenza (HPAI) consideration of ventilation shutdown (VSD) - gov.scot (www.gov.scot)

[17] Wathes, C. (2010), Lives worth living?. Veterinary Record, 166: 468-469. https://doi.org/10.1136/vr.c849

57. Although outside AWC's remit, government should consider whether there is a risk of environmental toxicity from some constituents of the high expansion foam. Any use of chemicals in the foam deployment should be monitored and subject to local discharge regulations to avoid harm to the environment.

58. Field based research trials on the use of high expansion Nitrogen foam have not been undertaken on species other than broiler chickens, broiler breeders and adult laying hens. However, it is reasonable to extrapolate the physiological consequences of being submerged in high expansion Nitrogen foam from broiler chickens and adult layer hens to other species and life stages, although it could take longer for some to become unconscious.

59. No field trials have been undertaken using high expansion Nitrogen foam in non-floor-based systems. It is currently not possible to complete an evidence-based harm:benefit analysis of using high expansion Nitrogen foam in other systems e.g. tiered colony systems. Given the potential welfare advantages offered by the use of high expansion Nitrogen foam there is an urgent need for such field trials underpinned by science or further laboratory studies to be undertaken.

60. Taking all of these factors into account and using the ethical approach described above, the availability of high expansion Nitrogen foam as a method of depopulation of litter-based systems housing broiler chickens, broiler breeders and adult laying hens and (by extrapolation) other species of poultry is ethically desirable.

Conclusions

61. High expansion Nitrogen foam is an effective method of killing poultry which offers some advantages in terms of welfare impacts over some other currently used methods. It should be available for immediate deployment for disease control and other emergency applications as an effective method of culling poultry. However, its use should always be informed by consideration of its suitability in the context of each individual situation, with particular thought given to house design, poultry species, and possible environmental contamination. The use of high expansion Nitrogen foam as a method of depopulation can be considered equivalent or better for poultry than the use of WHG with CO_2, and equivalent or better than the use of CGUs because live handling of birds is not required. This has been evidenced in field-based research trials with broiler chickens, broiler breeders and adult layer hens.

62. Low and medium expansion foams occlude the airway and cause death by hypoxia, which is equivalent to drowning or suffocation and is not recognised as humane under domestic and European legislation nor the 2018 World Organisation for Animal Health (WOAH) guidelines on the killing of animals for disease control purposes[18]. They should not be used for culling poultry.

63. The need for lengthy and expensive primary research on the use of high expansion Nitrogen foam in species other than those which have already been studied can be avoided as the anoxic effect of high expansion Nitrogen foam can be expected to affect all poultry species in a similar way physiologically, i.e. all species

[18] https://www.woah.org/fileadmin/Home/eng/Health_standards/tahc/2018/en_chapitre_aw_killing.htm

will succumb at levels of Oxygen below 1%, although some may take longer to lose consciousness than others.

64. Preferred species and housing types for the application of high expansion Nitrogen foam are litter-based broilers, broiler breeders, meat turkeys and meat ducks, because these have been tested with the foam delivery system. Litter-based turkey breeders and duck breeders are also housed in a similar layout to broiler breeders. There is a need to do field trials using housing systems other than floor-based and with different species and ages of birds. Evidence is required on possible differential behavioural responses to the foam carrier depending on bird age or poultry species/type. Use of low lighting should be considered to reduce behavioural reactions.

65. It is difficult to monitor welfare directly once birds are submerged in foam. Methods of monitoring behaviours and unconsciousness of birds in the foam are needed to ensure consistent application of the killing method across the flock. These could include multiple gas monitors and camera systems (including infra-red in the dark) in each shed. Assessors should also plan to extract a sample of birds in shorter time than seen in recent trials to assess unconsciousness and death.

66. A derogation from PATOK Article 5 requirements pertaining to monitoring or visualisation of individual birds at the point of killing should be considered given confidence generated by the scientific studies on this method for killing poultry.

67. Placing of foam generators in the shed to generate a broad foam ‘wave’ from both ends is important to prevent birds gathering at edges or in corners and lowers risk of smothering. Monitoring and adjustment of the bow wave of foam by the operators to ensure sufficient coverage of birds with foam throughout the kill is very important.

68. Where depopulation is being undertaken for disease control, welfare harms associated with culling methods should be assessed against the welfare impact upon poultry of infection and death (e.g. from HPAI).

Recommendations

69. Government should authorise the use of high expansion Nitrogen foam in emergencies as an effective method of culling poultry, if necessary through a derogation under Article 18(3) of PATOK, in situations deemed appropriate by the Competent Authority/APHA and taking account of the welfare considerations outlined in this Opinion.

70. Low/medium expansion foam must not be used for culling of poultry.

7. The conditions for using high expansion Nitrogen foam must include:

- Oxygen monitors at regular intervals along the length of the shed at bird level that can be read and recorded. The results of research provide confidence that birds with minimal Oxygen available will become unconscious within 30 seconds
- CCTV cameras situated such that the bird behaviour prior to submersion in the foam and the progression of foam fill throughout the shed can be

observed from a position outside of the building. Cameras provide evidence that birds are not subjected to any undue distress and all birds in the shed are engulfed by the foam to a sufficient depth to ensure rapid loss of consciousness and death.

- Assessors should also plan to extract a sample of birds in shorter time than seen in recent trials to assess unconsciousness and death.
- Maximum exclusion of light possible, to reduce the visual impact of the foam.

72. Further work should be carried out on the structure of the foam delivery to improve flow over birds, reducing the height of fill to, for example, 1 metre above bird height. This would enable foam to be dispersed faster after the depopulation cull had been completed and permit checks to be performed on the birds as quickly as possible after the event.

73. High expansion Nitrogen foam should be used, when possible, in open sided flat floored sheds in preference to CGUs to eliminate the stress that results from catching. The first usages of high expansion nitrogen foam under such circumstances should be fully monitored by APHA and alternative killing arrangements must be in place in case the birds show a stress reaction likely to result in harm.

74. Trials should be undertaken in empty caged sheds to evaluate the ability of the foam to flow through and around complex structures, including nest boxes.

75. High expansion Nitrogen foam should not be used in multi-tiered sheds without further research to establish the effect of birds perhaps becoming unbalanced before becoming unconscious and falling from the higher tiers onto those below.

76. Evidence is required on possible differential behavioural responses to the foam carrier depending on bird age or poultry species/type.

77. A derogation to parts of PATOK Article 5 should be considered by Governments to permit the killing of poultry to control notifiable disease outbreaks by depopulation using high expansion nitrogen foam without being able to observe the birds throughout the process.

78. Any use of chemicals in the foam deployment should be monitored and subject to local discharge regulations to avoid harm to the environment

Glossary

APHA – Animal and Plant Health Agency

AWC – Animal Welfare Committee

Anoxia - The absence, or near absence, of oxygen

Anoxic – of, relating to, or affected with anoxia

Asphyxiation - the state or process of being deprived of oxygen, which can result in unconsciousness or death

Ataxia – a lack of muscle coordination and control

Cerebral hypoxia - when the brain is not getting enough oxygen

CGU – Containerised Gas Units

Depopulation – Process of killing animals for public health, animal health, animal welfare or environmental reasons under the supervision of the competent authority

EEG – electroencephalograph

EFSA – European Food Safety Authority

FAWC – Farm Animal Welfare Committee

Hyperventilation – rapid or deep breathing, usually caused by anxiety or panic

Hypoxia - low levels of oxygen in the body tissues

PATOK – Retained EC Regulation 1099/2009 on the protection of animals at the time of killing

Surfactant - a substance which tends to reduce the surface tension of a liquid in which it is dissolved

WHG – Whole House Gassing

WOAH – World Organisation for Animal Health

Zoonotic - an infectious disease that has jumped from a non-human animal to humans

APPENDIX 1: Membership of AWC

*Prof Madeleine Campbell—Chair
Dr Gareth Arnott
Ms Emily Craven
*Dr Jane Downes
*Dr Troy Gibson
Prof Simon Girling
Dr Julian Kupfer
*Mr Stephen Lister
*Dr Dorothy McKeegan
Dr Romain Pizzi
*Dr Pen Rashbass
Prof Sarah Wolfensohn
Dr Julia Wrathall
Dr James Yeates

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