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A pilot study to assess whether high expansion CO_2-enriched foam is acceptable for on-farm emergency killing of poultry

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Abstract

This pilot experiment was conducted to ascertain whether CO_2-enriched high expansion foam could be an acceptable and efficient alternative in emergency killing of poultry. This method could have wide-ranging applications but with particular emphasis on small (backyard) flocks, free-range sheds or open (naturally-ventilated) housings. The objectives of the study were as follows: 1) to determine whether the injection of foam and being covered with foam leads to fear or panic reactions in birds; 2) to determine the time taken to render birds unconscious and dead and 3) to determine whether any pathological abnormalities are observed post mortem. Six laying hens were individually exposed to increasing levels of CO_2 foam with an expansion rate of 300:1. The test box containing individual birds filled with foam within 30 s. During foaming, two out of six birds tried to escape from the test box (1–2 attempts per bird). Apart from displaying greater alertness, birds showed no aversive reactions to the CO_2 foam. Twenty-to-thirty seconds after being covered with foam, five of the six birds demonstrated one or two forcable or convulsive movements. Movement patterns and muscle jerks immediately following this convulsive movement led us to believe that birds lost consciousness at this moment and, within approximately three minutes, all birds had ceased to have a heartbeat. Macroscopic post mortem examination of the birds revealed no abnormalities and microscopic examination showed moderate bronchiolar bleeding and a small amount of alveolar bleeding. After assessing behavioural parameters, measurements of heart rate and pathological data, it is our conclusion that CO_2 foam has the potential to be an acceptable method of killing poultry. It is advisable for this method to be examined on a larger scale in order to assess the implications of physiological (EEG and ECG) measurements on welfare.

Keywords: *animal welfare, carbon dioxide, emergency killing, euthanasia, foam, poultry*

Introduction

Outbreaks of highly pathogenic avian influenza have necessitated the large scale killing of poultry that have either contracted or been exposed to the disease. For instances in which this has occurred in commercial poultry flocks, one of the methods deployed is gassing the birds in their growing sheds, thereby reducing the need for personnel to enter the shed and collect live, infected birds (Gerritzen *et al* 2004, 2006b). In Europe, this requires doors, ventilation openings and other small holes in sheds to be sealed up, while in the US a polythene tent is constructed over the birds. Carbon dioxide is then introduced into the enclosure to kill the birds. Both methods require personnel to enter the shed to seal it. An alternative, more efficient way of delivering gas to birds in a shed or container has been proposed; to use gas-filled foam (Kiezebrink 2007). The potential advantages of this system would be that as the gas is contained in the foam, the building or pen would not have to be sealed and far less people would be needed to manage the operation.

The use of standard firefighting foaming equipment has been tested and deployed in the United States in an attempt to reduce the number of people potentially coming into contact with the virus. Trials of foaming systems to date (Dawson *et al* 2006; Benson *et al* 2007) have used medium (ie expansion rate in fire-fighting terms is defined as the ratio of volume of liquid to the volume of foam produced; in general, low expansion foam has a ratio up to 20:1, medium up to 200:1 and high over 200:1) fire-fighting foam to create a blanket over the birds to restrict oxygen availability, so that the birds die of hypoxia. The structure and size of the foam used in these trials was such that small bubbles were found in the airways of the birds. The conclusion reached was that the foam caused an occlusion of the airway, meaning that birds typically expire as a result of hypoxia. However, issues regarding animal welfare still require to be addressed and the need to optimise and/or modify foam-killing methods is well recognised.

It is suggested that two possible options exist for optimising the foam-killing method, maintaining the efficacy of the method while at the same time reducing the negative effects on animal welfare. The first aspect is to increase the diameter of the foam bubbles to prevent airway occlusion. The second is to add a gas or mixture of gases to the foam to induce rapid unconsciousness prior to death. The aim of the present pilot study is to combine an increase in bubble size with an anaesthetic or lethal gas. More precisely, it is intended to create conditions of hypercapnia, thereby inducing unconsciousness that is followed by death. It was hoped that the findings of this pilot study would determine whether CO_2-enriched foam is an acceptable method of emergency killing in poultry. To this end, the aims of our study were as follows: to determine whether foam injection and subsequent immersion leads to fear or panic reactions in birds; to determine the time taken for a high expansion foam containing bubbles of 100% CO_2 gas to render birds unconscious and dead and to determine whether there is foam or water in the lungs, abnormalities (ie bleeding) in the brain or other organs and visible irritation of the eyes and or airways.

Materials and methods

The equipment that was used in the trial was supplied by LST International (Epe, The Netherlands) and creates a carbon dioxide-rich environment around the birds which is readily inhaled, leading rapidly to unconsciousness followed by death. This is achieved through generation of high-expansion foam with bubbles containing 100% CO_2. The size of the bubbles ensures birds are killed as a result of exposure to the gas and not by occlusion of the airway. Ethical aspects of the experiment were judged and approved by the animal ethical committee of the institute.

Foam

The foam is based on a commercially-available fire-fighting foam (Ajax HTF 1000, Ajax Fire Security, Amsterdam, The Netherlands) but with a number of modifications; most notably the expansion rate and the levels of CO_2 contained in the foam. The foam is generated by blowing high pressure CO_2 gas over a pre-mixed solution of 3% concentrate (2-butoxy-ethanol) through a specially-designed foam generator. In this way a high expansion (~300:1) foam is generated with bubbles (10–50 mm in diameter) filled with 100% CO_2.

Animals and test situation

Six 50-week old laying hens were fitted with a transmitter (TA11CTA-F40, Data Science International, St Paul, Mn, USA) to measure temperature and heart rate during each foaming experiment. The transmitters were modified to be used externally on the animals. Two silver (55% silver, 21% copper, 24% zinc) spiked electrodes (2.5 cm long and with a diameter of 0.1 cm) were connected to the 10 cm long transmitter leads. The electrodes were punctured subcutaneously on to the right and left of the chest and the transmitter with the leads was fixed externally to the chest using medical tape bandage. Immediately following transmitter attachment, animals were placed into the test box and the signal checked. This was received by four linked BMC receivers under the base plate of the test box.

The test box (0.94 × 0.84 × 0.80 m; length × width × height) was constructed of four wire mesh side walls, a Perspex floor and four removable Perspex side plates at the inside of the wire mesh cage. A digital camcorder was placed above the test box for recording birds' behavioural parameters. The camera covered the entire test area.

During foaming, CO_2 concentration was measured using a CO_2 Guardian Measurement Unit (PBI, Dansensor, Ringsted, Denmark) with a range of 0–100%. Concentration was measured immediately above the foam and also within the foam, but the number of measurements taken was limited by the build-up of moisture in the sampling tube.

Pathology

A complete macroscopic necropsy was conducted to determine pathological changes or damage to different organ systems, with particular attention paid to bleeding and foam or water in the airways and bleeding in brain, liver or kidneys. Microscopic analysis of brain and lung tissue were also conducted.

Results

The pH-neutral CO_2 foam was generated with an expansion rate of approximately 300:1. Within approximately 30 s (range 24–40), the test box was filled completely with foam (see Figure 1). Birds were immersed in CO_2 foam within approximately 20 s (range 12–40). The CO_2 concentration in the zone 10 cm above the foam ranged between 40–75% while, in the foam itself, levels of up to 78% were recorded. The latter measurements were affected by moisture sucked into the measuring tube and cannot be taken as exact.

Behaviour

Attempts to escape such as jumping and wing flapping at the onset of foam injection were observed in two of the six animals; in one instance there was one single action at the beginning of the foaming process whilst in the second there were two; immediately prior to the onset of foaming and again at the point of submersion. Outwith these reactions, all the birds remained quiet and stationary in the test box although all were visibly more watchful and alert. Prior to complete immersion in the foam, headshaking was observed in one bird and gasping in another two. Gasping was characterised by mild, deep breathing without bending the neck backwards. Directly after immersion, two birds jumped up once. This strong movement could not be classed as a convulsion and was more akin to an attempt to escape. Forceful activity that could be classed as convulsions were seen in five of the six birds at between 30 and 56 s after the start of foaming. The convulsive movements (ie strong, uncontrolled leg and wing movements) were observed in four out of six birds, followed by wing flapping from an average of 60 s after the onset of foaming.

Temperature and heart rate

Shortly before foam injection the average skin temperature of the hens was 25.4°C and during foaming this rose to 27.4°C. The heart rate (Figure 2) was measured for

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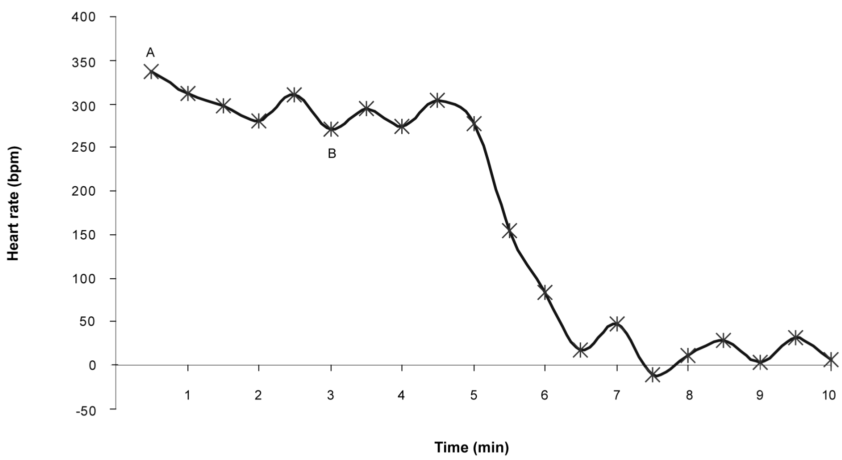
Figure 1

View of chicken in test box, 20 s after foaming.

Figure 2

Heart rate (bpm) of one bird during the foaming experiment. Heart rate was measured and averaged over 10 s every 30 s. Noise interference on the signal trace meant that the bpm did not stabilise on the x-axis. A: start measuring; B: start foaming.



three minutes prior to the onset of the foaming process. During this period all the birds showed a regular heart rate of approximately 300 bpm (range 270–370). During foaming no major changes in heart rate were observed until the heart instantly ceased beating. This instant decline in heart rate occurred at an average of two minutes (range 1.2–4.5) after the onset of foaming. After this instantaneous drop some irregular phases of heartbeat were observed prior to the cessation of any signal.

Pathology

Macroscopic post mortem observations revealed no abnormalities on the exterior of the birds and no internal abnormalities were observed in the thorax and abdomen, cardiovascular system, spleen, liver, gastrointestinal system or central nervous system. Five out of the six birds had traces of saliva in the tracheae and, in one, moderate redness was observed in the lungs. These airway abnormalities were classed as minor to moderate changes and no foam or soap were found in the lungs or airways. Liver and brain microscopy showed no abnormalities. All six animals showed evidence of bleeding in the tertiary bronchiole, with a number of others showing bleeding in the interstitial bronchiole. Histological examination revealed two out of six individuals with alveolar bleeding.

Discussion

Birds showed minimal fear behaviour during foaming although all birds displayed greater alertness during foaming compared to prior to injection. A degree of headshaking and gasping prior to birds being covered with foam indicates an effect of free CO_2 at the periphery of the foam.

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Convulsive movements, wing flapping and leg-shaking are also seen during gassing with CO_2 (Gerritzen *et al* 2006a, 2007) and were observed to occur at or just after loss of posture and are therefore indicative of loss of consciousness. Based on this assumption, it can be concluded that loss of consciousness occurred within one minute of the onset of foaming. However, it must be noted that the moment of loss of consciousness was not directly measured in this pilot study.

The acute drop in heart rate to zero or very close to zero indicates an acute death of the animals. This point, in conjunction with no observed bleeding in brain tissue — which is indicative of asphyxia and hypercapnic hypoxia — makes it most likely that death arose for metabolic reasons; in this instance due to the high levels of CO_2 (N Stockhofe personal communication 2007). The only pathological abnormalities observed were bleeding in the bronchiole and alveolar tissues. Taking these findings in the context of having no previous studies with which to draw comparison, it is difficult to draw any conclusions on the cause of this bleeding. However, bleeding such as this is also reported for CO_2 gassing experiments (Ryan 2006).

The objective of this pilot study was to detect whether CO_2-enriched high expansion foam has the potential to be an acceptable and efficient method for emergency killing of poultry. When we take into account behavioural parameters, measurements of heart rate and pathological data, it is our conclusion that CO_2 foam is a potentially acceptable killing method for laying hens. Furthermore, the authors advise an examination of this method on a larger scale in order to explore the implications for animal welfare of physiological (EEG and ECG) measurements. It is also suggested that a comparison of different types of foam, different bubble sizes and different gases or gas mixtures, eg nitrogen (ABM Raj personal communication 2008) be carried out to create a bank of knowledge on this subject.

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