Controlled Atmosphere Stunning

E. Lambooij and M.A. Gerritzen

Wageningen UR, Live stock research, P.O. Box 65, 8200 AB Lelystad, The Netherlands

* Corresponding author: bert.lambooij@wur.nl

Abbreviated title: Controlled Atmosphere stunning

Summary

Controlled atmosphere (CAS) stunning includes several variations of gaseous mixtures given to induce an anaesthetic state before slaughter poultry. One method of multi phase CAS is to unload the birds out of the crate on a conveyor belt and subject the birds to an atmosphere of 30% O_2, 40% CO_2 and 30% N_2 for 1 min to stun them followed by an atmosphere of 80% CO_2 and 5% O_2 for 2 min.

Another approach of CAS involves exposure of poultry while remaining in the crates in a chamber to a mixture of inert gasses to produce anoxic loss of consciousness. This approach includes killing with a number of different gasses by anoxia such as Ar and N_2 content up to 90% with a CO_2 content limited to 30% and O_2 maximised by 2%. Initially Ar and O_2 were used in contents of > 90% and 2%, respectively. At present N_2 and Ar with/ or without CO_2 for broilers and N_2 with CO_2 are used for turkey.

After stunning the birds are shackled, exsanguinated and slaughtered.

CO_2 is an anaesthetic gas which produces rapid unconsciousness when inhaled at high concentrations, however, signs of asphyxia and behavioural excitation are observed due to occurrence of both hypercapnia and hypoxia. More over, it is an acidic gas. It is likely that an avoidance response is mediated by the olfactory system in birds.

Exposure of birds to 90% Ar in air or 60% Ar / 30% CO_2 in air results in an anoxic condition. Anoxia results in suppression of the rostral reticular formation and therefore loss of consciousness and in suppression of the caudal reticular formation and therefore onset of convulsions. Wing flapping is observed before the onset of loss of posture when exposed to Ar or Ar / CO_2 gas mixtures.

Keywords: poultry, gas stunning, welfare, meat quality

Introduction

According to the EU Council Directive (1993) on the protection of animals at the time of slaughter it is stated that horses, ruminants, pigs, rabbits and poultry brought into abattoirs for slaughter shall be a) moved and if necessary lairaged, b) restrained and c) stunned before slaughter. Animals must be restrained in an appropriate manner, so as to spare them any avoidable pain, suffering, agitation, injury or contusions. Animals must not be suspended before stunning or killing. However, poultry and rabbits may be suspended for slaughter provided that appropriate measures are taken to ensure that they are in a sufficiently relaxed state for stunning. Permitted methods for stunning are 1) captive bolt pistol, 2) concussion, 3) electro-narcosis and 4) exposure to special gas mixtures. Special requirements are mentioned in the ANNEX C for stunning of slaughter animals. For gas stunning, there are only requirements for pigs. A special licence from the competent authority is necessary to use gas for stunning of poultry. In the proposal for the new Council Regulation gas stunning methods for poultry are listed in the ANNEX 1 with special requirements for CO_2 concentration, duration of exposure, stun-to-stick interval, quality of the gas and temperature od the gas.
Stunning of animals is in the first place applied to induce a state of unconsciousness and insensibility of sufficient duration to ensure that the animal does not recover before death intervenes via exsanguination. Secondly stunning should produce sufficient immobility to facilitate the initiation of exsanguination. It is generally stated that unconsciousness should be induced as soon as possible without a detrimental effect on the welfare of the animal and the meat quality of the carcass (Blackmore & Delany, 1988). For the application of stunning methods it is necessary to confine or restrain the animal and to line up before the stunning itself.

Stunning by captive bolt was introduced at the end of the 19th century, electrical stunning at the end of the 1920's and CO_2-gas stunning in the 1950's. The Controlled Atmosphere Stunning (CAS) is introduced in the late 90's of the former century and this method will be described here.

Welfare

Pain can be described as an aversive and sensitive experience representing an awareness of damage to the tissues (Molony and Kent, 1997). The purpose of anaesthesia is to remove this awareness. Inhalant anaesthetics can be very effective in this respect. They evaporate readily at room temperature and can therefore be administered via the airways. They cause a depression of the central nervous system, resulting in muscle relaxation and loss of consciousness.

Inhalation anaesthesia also has limitations. An overdose leads to paralysis of the respiratory muscles, which leads to death by suffocation. In addition, during induction there is an excitation phase, i.e. a period of increased activity and strong uncontrolled movements. Compared with injectable anaesthetics, this phase lasts for a long time. The weaker the anaesthetic effect, the longer the excitation phase.

A problem when administering gases is that of excitation, a stage of increased activity and strong uncontrolled muscle movements. The animals are not always unconscious at this stage, so this can result in distress (Dannemann, 1997; Lambooij et al, 1999). High concentrations of (CO_2) produce a high level of excitation. A mixture with a low CO_2 + a high O_2 concentration (e.g. in broiler chickens) produces virtually no excitation (Coenen et al, 1995; Coenen et al, 2000; McKeegan et al, 2007). The duration and intensity of excitation depend on the gas mixture, the way in which it is administered, and the breed of animal. Exposure could be stressful to animals as it may impart a sense of breathlessness (Raj *et al*, 1992, Raj & Gregory, 1991) and stimulate a warning system.

A low dose of CO_2 (approx. 20%) also has a narcotic effect in several animal species (Dannemann et al, 1997; Gerritzen et al, 2006). CO_2 is often used in combination with other gases, producing potentiation and/or reduced excitation, but

the mechanism is not always clear. An example is reduced excitation if a combination of CO_2 and O_2 is used (Coenen et al, 1995; McKeegan et al, 2003, 2005).

An excessive rise in pCO_2 in the blood eventually leads first to respiratory depression, then to respiratory stimulation, thereby creating a vicious circle that ends in death (Guyton and Hall, 1994). The normal pH value of this fluid is 7.4, and a state of unconsciousness is induced if this falls to 7.1 (Eisele et al, 1967). If blood pH in pigs falls to 6.6, death may result (Martoft, 2001). This value has also been measured in ducks and turkeys, and the animals died (Gerritzen et al, 2006). Changes in the pH of the blood affect enzyme reactions that relate to energy production, changes in membrane permeability and electrolyte balance. This appears to be the point at which regeneration is no longer possible.

Gas mixtures

An alternative stunning system to the generally applied electrical water bath stunner for broiler chickens is gas stunning. A lot of gas mixtures can be used to stun or kill animals, however, for slaughter animals the use is restricted. At present the gas mixtures 90% Ar (argon) in air, 30% CO_2 and 60% Ar in air and 40% CO_2 and 30% O_2 (oxygen) and 30% N_2 (nitrogen) are used for poultry in a few plants under commercial conditions (Hoen & Lankhaar, 1999).
The used gasses can be divided in gasses, such as N_2 or Ar, that displace O_2 from the air to be breathed and gasses, such as CO_2 (in concentrations higher than 12%), that affect directly the central nervous system (Boogaard *et al*, 1985). A problem with O_2 - replacers is its lower efficacy in younger animals (Wooley & Gentle, 1988). However, Ar can be easily administered in gas stunning, because it is heavier than air (as is CO_2), tasteless and odourless. Another option is a low concentration of CO_2 in Ar. Research has shown that both last mentioned gas mixtures caused a rapid loss of brain function in chickens (Raj and Gregory, 1991; Raj *et al*), turkeys (Raj & Gregory, 1994).

It is concluded that during the immersion in gas mixtures broilers show gasps, head shakes and wing flapping which start before loss of posture, which may cause some distress. However, it can be argued that gas stunning compared to water bath stunning is preferred in practical applications, because the live broilers do not need to be uncrated and / or shackled Lambooij *et al*, 1999).

Meat quality

Differences in the rate of post-mortem glycolysis, induced by other stunning procedures, like gaseous stunning, have been reported to result in differences in meat quality traits, like colour and texture (Raj, 1994). When compared with the high frequency electrical stunning, Ar killing of broilers resulted in less bleed-out and this might contribute to the prevalence of carcass downgrading.

Gas mixtures and electrical stunning methods showed different effects on meat quality (Uijttenboogaart, 1997). Blood clotting incidence was lower in CO_2 gas stunning systems compared to electrical stunning. The liver from gas stunned birds was darker, more red and less yellow compared to electrical stunned birds. Breast meat of CO_2 stunned birds is lighter than from electrical and Ar stunned birds. Haem content in liver and breast meat is also affected by the way of stunning. Breast meat of gas stunned birds have significant higher levels compared to electrical stunned birds. Furthermore levels in the liver tend to be lower in the gas stunned birds. For practical use of gas stunning systems attention should be paid to the duration and intensity of the picking operation, due to .the number of feathers left on the carcass. Ar stunning affected the pH with a sharp decrease compared to the two other systems of stunning (electrical and CO_2). Probably due to the convulsions that occur during the stun/kill operation in Ar the pH of the meat is already lower than with the stunning operations at which no or less convulsions occur. After 24 hours of chilling no differences are shown between the stunning methods used. A very significant effect of ageing/boning on shear, water binding and sensory parameters have been found. Differences in the rate of post-mortem glycolysis, induced by other stunning procedures, like gaseous stunning, have been reported to result in differences in meat quality traits, like colour and texture (Raj, 1994). When compared with the high frequency electrical stunning, Ar killing of broilers resulted in less bleed-out and this might contribute to the prevalence of carcass downgrading.

Quality defect

Haemorrhaging results in a decrease in quantity (trimming) and quality of poultry products, and hence causes economical losses to the poultry industry. Therefore haemorrhaging, in particular of the valuable breast meat, is

considered a major quality defect. Haemorrhages can be induced by stunning, however, the underlying mechanism is considered to be multifactorial (Kranen *et al*., 1996).

The morphology of haemorrhages investigated was dependent on the tissue in which they occurred. In the pectoral muscles extravasating blood was found to follow the direction of the muscle fibres. In fat tissue, the majority of the haemorrhages had a petechial appearance. More diffuse haemorrhages were found in loose connective tissue. (Kranen et al, 2000). The histological study of haemorrhages in different types of muscles showed that the morphological appearance of the blood extravasation is determined by the structure of the tissue as well as by the amount of blood leaving the circulation. Some haemorrhages were associated with hyper contracted and disrupted muscle fibres, indicating that they were caused by severe muscular strain. Many haemorrhages were found near venules or veins packed with erythrocyte, surrounded by intact adipocyte and connective tissue. Rupture was observed only in venous structures, like post-capillary venules and small veins, not in arterial vessels. It strongly indicates that a local rise in venous blood pressure can cause rupture of venules and small veins (Kranen et al, 2000). A higher incidence of wing damage after gas stunning, compared to electrical stunning, has been observed in a study of Raj *et al*. (1992). Wing damage in that study was due to the severe convulsions caused by gaseous stunning. Gas killing of broilers would substantially reduce the incidence of broken bones and haemorrhaging in breast muscles in association with or without the broken bones (Raj, 1997; Uijttenboogaart, 1997).

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