Stunning systems of poultry species

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Introduction

In the distant past large animals were sometimes stunned by a heavy blow on the head where poultry was decapitated before slaughter

During the last century concern for animal welfare increased. Concussion stunning was deemed not satisfactory, and improved stunning methods were developed. 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.

A basic requirement for humane slaughter of animals including poultry is that they should be stunned, rendered unconscious and insensible, prior to slaughter by exsanguination. Under commercial conditions, red meat animals (horses, ruminants and pigs) are stunned using either a penetrating captive bolt, non-penetrating concussion bolt, electric current or carbon dioxide gas, poultry species are stunned using electrified water bath. There are two main reasons for this common practice in poultry. Firstly, it may be difficult to apply captive or concussion bolt owing to a very small target area (head) for shooting in poultry without compromising bird welfare under commercial conditions. Secondly, the throughput rates required in medium to large chicken processing plants (killing 5 to 9 thousand birds per hour) can be easily achieved with water bath stunners rather than with captive bolt or concussion stunners.

An alternative stunning system to the generally applied electrical water bath stunner for broiler chickens is gas stunning (CAS = Controlled Atmosphere Stunning). This method of stunning can eliminate the stress associated with uncrating and / or shackling of live birds prior to electrical stunning.

Legislation

Stunning of slaughter 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 while bleeding to death (exsanguination). Secondly, stunning should produce sufficient immobility to facilitate the initiation of exsanguination. It is generally stated that unconsciousness and insensibility should be induced as soon as possible and without a detrimental effect on the welfare of the animal and the meat quality of the carcass.

According to the EU Council Directive of 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.

Electrical and gas stunning is generally used to induce unconsciousness during cutting and bleeding for reasons of animal welfare in the EU or to induce immobilisation to facilitate automatic neck cutting in the USA.

The Treaty of Amsterdam (EFSA – AHAW/04-027, 2004) has set new rules for the actions of the EU in a “Protocol on the Protection and Welfare of Animals”. It recognises the sentience of animals and requires that European Institutions pay full regard to the welfare requirements

of animals in the formulation and implementation of Communityregulations. Animals should be protected from any avoidable excitement, pain or suffering during transport, lairaging, restraint, stunning, slaughter or kill ing.

Electrical stunning

Electro-anaesthesia

A special method of electro-anaesthesia is widely used for the stunning of slaughter animals. The stunning method is based on the induction of a general epileptiform insult (grand mal or seizure-like state) by the flow of an electrical current through the brains. If sufficient current is administered through the brain of an animal a general epileptiform insult (all brain parts are stimulated) will occur. The epileptic process is characterised by rapid and extreme depolarisation of the membrane potential and there is heterogeneity of findings. As measured on the EEG (electro encephalogram) such an insult consists of relatively small waves increasing in amplitude in the tonic phase, and decreasing in frequency in the clonic phase to result ultimately in a period of strong depression of electrical activity in pigs, sheep and calves. The general epileptiform insult on the EEG of some birds and fishes is characterised by a tonic/clonic phase and an exhaustion phase. The duration of the insults differs between species. A minimum current, which is a function of the electrical impedance of the body, is necessary for the occurrence of such an insult.

A human being is unconscious during the three phases of a general epileptiform insult. By analogy, a vertebrate is also considered to be unconscious and insensible during such an insult. The analogy postulate is used to make the existence phenomena in vertebrates plausible. The postulate rests on the homology of brain structures and similarities in behavioural pattern between humans and vertebrates in situations in which humans experience and report positive or negative feelings More over, the brain is in a stimulated condition and unable to respond to stimuli. Another fact is the release of several neurotransmitters in the brain during such an insult. Several studies in which neurotransmitters have been measured, coupled with pharmacological experiments, suggest the general epileptiform insult induced by an electrical stun is dependent on the release of vasopressin, oxytocin, glutamate, aspartate and GABA (gamma amino-4-butyric acid). The first phase induced by the stun produces the tonic phase through the release of the excitatory neurotransmitter glutamate. This is followed by the release of GABA that assists in the recovery if the animal is not killed.

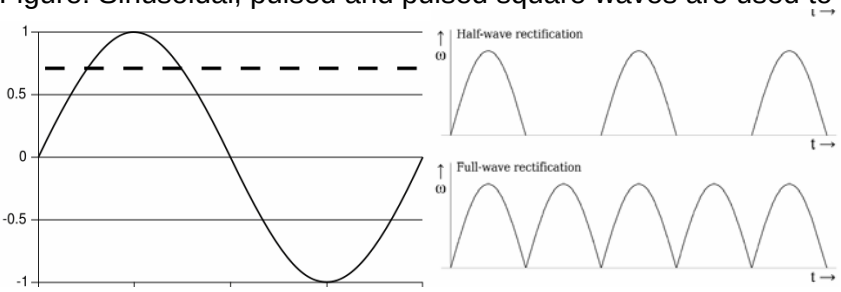
Brain tissue impedance (ECV) has been used as a measure of changes in the extracellular volume and it has been found to be a valid indicator in ischaemia-induced brain damage experiments with broiler chickens. Animals that were bled only showed a decrease in base extracellular volume after four minutes post mortem, while electrical head-body stunning, inducing cardiac fibrillation, caused an immediate and gradual increase in brain impedance. This suggests that the last method provides an immediate effect on the brain. Head-only stunning with exsanguination caused a dual response pattern. Some animals showed a response similar to animals that were bled only, and some animals were similar to those experiencing head-body stunning. Various physiological processes may contribute to this effect. It cannot be concluded from this experiment that head-only electrical stunning in all cases provides an adequate stun.

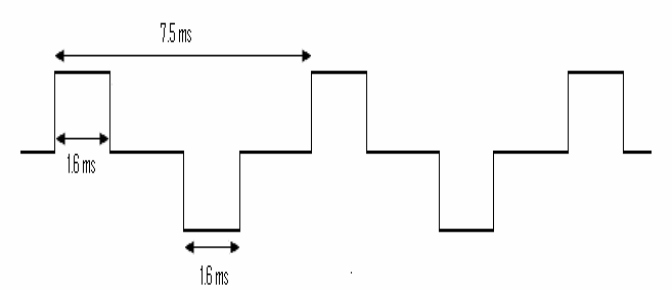
Water bath stunning

It is common that poultry are hung by the legs from shackles and stunning is done electrically by immersion of the head and neck of the bird in an electrified water bath In a water bath, in which electrical current is applied to the whole body, a minimum current of 120 mA (50 Hz) per bird is recommended to induce unconsciousness and a cardiac arrest. A heart failure is recordable on an ECG (electro-cardiogram). As in the brain, in the heart the neuronal interactions are integrated and orderly. Disorder is initiated by direct stimulation by electric current and the heart will fibrillate or stop. The heart failure results in loss of blood pressure and lack of oxygen to the brain and affects the characteristics of general epileptiform insult.

The in the EU recommended minimum current for broilers of 120 mA increases quality defects (haemorrhages, broken bones) of carcasses and meat. It is apparent that there is a conflict between welfare and meat quality in the electrical water bath stunning and/or killing procedure.

Figure: Sinusoidal, pulsed and pulsed square waves are used to stun poultry





The most common electrical stunning method for livestock uses a 50 Hz alternating current (AC) with sinusoidal waveform. At present a variety of wave forms and frequencies of currents can be supplied. Alternatives for the sinusoidal AC current are pulsed direct and pulsed alternating currents. It is suggested that the depth and duration of unconsciousness induced by the electrical stunning is determined by the duration for which the current stays at the minimum level within each cycle (RMS-current, duty cycle, AC/DC).
Due to the frequency in relation to wave form and current immobilisation, sleep, anaesthesia, stunning and convulsive (therapy) can be induced Stimulation of the cortex and brain stem using 50 to 300 pulses per s may introduce desynchronised sleep. Anaesthesia may be induced by stimulation with 100 to 100,000 cps using a duration of 3 ms and 18 mA. Spasms, irregular breathing and cardiac arrhythmia were induced with a longer duration or a higher current. Irregular rectangular pulse currents may decrease the muscular spasm(s). Stunning of slaughter animals is based on inducing a grand mal seizure or general epileptiform insult. . A DC constant current is introduced to immobilise animals to treat them and a 50 Hz low current is used to immobilise broilers for automatic cutting for bleeding.

Table: Minimal required current (mA per animal) in a water bath stunnerminaal.

Frequency (Hz)	broiler	turkey
< 200 Hz	100	250
200-400 Hz	150	400
400-1500 Hz	200	400

The most effective current seems to ones with 50 to 200 Hz. It is difficult to induce such a seizure by using frequencies lower than 25 Hz. When the frequency is between 200 and 1600 Hz a higher current is necessary to induce the seizure. A consequence is that the duration of the insult is shorter.

Welfare

The insight into the stunning process that has come from neuro-physiological studies is very important. Assessment of more parameters than the general epileptiform insult and the analgesia may support the humaneness of the stunning and killing system. EEG and neurotransmitter release measurements have been used to assess the effect of electrical head-only stun duration on welfare. An understanding of the physiological mechanisms underlying the effects of electrical stunning may help to clarify the effect of several conditions on the effectiveness of stunning and killing. Stress before killing increases some neurotransmitters, which may affect the post stun reflexes and unconsciousness. Combining head-only stunning with exsanguination has a synergistic affect on the release of glutamate and aspartate, which increases the duration of unconsciousness. Sticking following a stun should be carried out as promptly as possible when using head-only stunning as it takes time depending on the specie before brain responsiveness is lost following sticking. It is widely recognised that inducing a cardiac arrest at stunning has distinct welfare advantages: 1) it results in a rapid loss of brain function, 2) it ensures that the animal will not regain consciousness and 3) it does not depend on the operator performing an accurate stick.

A major point that deserves particular attention is whether stunning actually renders the animal unconscious and insensible. Although this is usually believed to be the case, recent experimental findings cast some doubts upon this assumption.

Mechanical stunning

Air jet

The development of captive bolt stunning has been negated in most species due to lack of means to prevent post-stun convulsions. Recently, a captive needle stunning method for broilers has been developed, in which air pressure is injected into the brains and partly directed to the spinal cord. The latter may prevent the convulsions. In broilers the air pressure stunning reduced post-stun convulsions to less than 13 % of the level of convulsions. The captive bolt stunning method for broilers has been modified, in which air pressure was used to block post stun convulsions. To improve the method for practical application a commercial air tacker was modified. The plunger of the original design was replaced by two needles, which penetrate the skin and skull at an angle of 15^{o} in caudal direction. Both needles were provided with small holes, which allow air through in different directions. The stunning position was at the intersection of two imaginary lines drawn from the ear on one side to the inner corner of the eye on the other side. A trigger starts the injection of compressed atmospheric air when the needles penetrate the skull, and the duration of air injection was electronically controlled. The duration of injection as well as the air pressure was adjusted to a shooting pressure of 8 bar and an air injection of 3 bar during 1.5 s. It is hypothesised that in the captive needle pistol the compressed atmospheric air administered through the needle, placed more anterior on the animals' head, damages higher brain regions to provide unconsciousness, while the other needle damages the upper spinal cord to prevent post stun convulsions. It is generally known that the removal of inhibitory influences from higher centres of the brain (e.g. damage by captive bolt), before the spinal cord becomes anoxic, results in convulsive activity and enhanced spinal reflexes.

Gas stunning

Gas mixtures

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 (carbon dioxide) and 60% Ar in air and 40% CO_2 and 30% O_2 (oxygen) and 30% N_2 (nitrogen) are used for poultry in different plants under commercial conditions.

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

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, turkeys and pigs.

Controlled atmosphere stunning
Controlled atmosphere stunning includes several variations of gaseous mixtures given to induce an anaesthetic state. 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 to kill them.
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. The current UK legislation allows the flexibility of killing with a number of different gasses by anoxia with the CO_2 content limited to 30% and O_2 maximised by 2%. Initially Ar and CO_2 were used, however, this was commercially unviable. At present N_2 and Ar with/ or CO_2 for chicken and N_2 with CO_2 are used for turkey.
After killing the birds they are shackled, exsanguinated and slaughtered.

Welfare
It is well recognised that 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 and has been found to be painful, causing unpleasant sensations on the nasal mucosa, lips and forehead in human subjects, when gas puffed stimuli are administered in concentrations over 65%. It is likely that an avoidance response is mediated by the olfactory system in birds. It is suggested that CO2 has aversive properties, particularly when inhaled at high concentrations. This has complications for the levels of CO2 to which conscious birds should be exposed during CAS.
Exposure of birds to 90% Ar in air or 60% Ar / 30% CO_2 in air results in an anoxic condition. Under these conditions depression of activity in the brain extends progressively from the telencephalon to the diencephalon and then to the mesencephalon. 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. This pointed to the suggestion that wing flapping during immersion in the gas might be a response to an anoxic condition. This may be supported by a study of physiological and behavioural responses in adult hens and chicks. When subjected to decreasing oxygen concentration adult birds slowly became unconscious, without showing any signs of distress, until respiratory failure supervened. Chicks showed similar results but loss of motor control was observed while still conscious, which might cause distress

Body effects
The CAS system eliminates the shackling of the live birds and transporting them head down to an electrical stunning device with the associated stress for the animals as well as the working environment and ergonomics of the hanging staff. The percentage of broken bones and blood spots is decreased which is caused by live bird hanging. More over, deboning is easier because there are virtually less broken bones and the deboning yield is higher as less meat has to be trimmed away.
During stunning in the CAS systems using inert gasses birds may show a lot of convulsions including wing flapping, which may result in broken bones and haemorrhages.

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