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Confidential report 304

High-low electrical head-only stunning of broilers

Hoog-laag kop-kop elektrisch verdoven van vleeskuikens

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Confidential report 304

High-low electrical head-only stunning of broilers

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December 2011

Voorwoord

In de 80-tiger jaren van de vorige eeuw is veel onderzoek in binnen en buitenland verricht naar effectief verdoven van pluimvee. De resultaten waren destijds helaas niet eenduidig. Toch is algemeen geaccepteerd en in regelgeving vastgelegd dat vleeskuikens met minimaal 100 mA per dier moeten worden verdoofd in een waterbad. Dit minimum wordt door verschillende onderzoekers te laag geacht. Algemeen wordt nu aangenomen dat bij de voorgeschreven stroomsterkte met een frequentie van 50 Hz nog 10% van de vleeskuikens niet effectief wordt verdoofd. Bij hogere frequenties en 100 mA zal dit percentage aanzienlijk hoger liggen. Voor deze frequentie wordt door de EFSA een hogere stroomsterkte geadviseerd. Een nadeel van deze hoge stroomsterkte is dat het vleeskuiken verkrampt. Dit veroorzaakt bloedingen in het karkas. Daarom wordt naar alternatieven voor deze werkwijze gezocht. De druk op alternatieven is toegenomen na uitbrengen van ASG rapport 200: elektrisch verdoven van pluimvee, dat duidelijk maakt dat het klassieke elektrisch waterbad verdovingssysteem in te veel gevallen niet volstaat. In het voorstel voor een nieuwe EU Richtlijn worden hogere stroomsterkten bij hogere frequenties verplicht gesteld. Het huidige waterbad wordt in Nederland uitgefaseerd.

Als alternatief voor de conventionele waterbadmethode is een verdover met kopdoorstroming in ontwikkeling. De neurologische en fysiologische effecten op het dier van het zogenaamde hoog-laag voltage kop-kop verdoven zijn niet bekend.

Samenvatting

Inleiding
In wetgeving is vastgelegd dat slachtdieren voorafgaand aan het doden door verbloeden op een adequate manier moeten worden verdoofd. Met een adequate verdoving wordt een directe staat van bewusteloosheid en ongevoeligheid bedoeld die aanhoudt tot de dood intreedt door verbloeden.
De meest toegepaste methode voor het verdoven van pluimvee een elektrisch waterbad waarin meerdere dieren (tot 25) tegelijk worden verdoofd. Door het verschil in elektrische impedantie tussen de dieren zal een deel van de dieren goed worden verdoofd maar zal ook een deel van de dieren niet worden verdoofd. Dieren met een hoge weerstand zullen een aanzienlijk lagere stroom dan de wettelijke 100mA krijgen toegediend en zullen hierdoor bij bewustzijn blijven. Dat niet alle dieren adequaat worden verdoofd is voor de Nederlandse overheid aanleiding geweest om het huidige waterbad te willen uit te faseren. Bij de herziening van de EU regelgeving voor het verdoven en doden van dieren (Council Regulation 2009) zijn de normen voor stroomsterkte en frequentie voor het verdoven van pluimvee aangescherpt om te voorkomen dat een deel van het pluimvee niet adequaat wordt verdoofd.
Naast een deel van de dieren die een te lage stroomsterkte krijgen toegediend is er ook een deel van de dieren die een hogere stroomsterkte krijgen toegediend wat resulteert in bloedingen in borst- en pootspieren en gebroken botten in het karkas. Om deze redenen wordt er naar alternatieve verdovingsmethoden gezocht. Een van de mogelijke alternatieven met perspectief zijn kop-kop verdovingsmethoden waarbij ieder dier individueel wordt verdoofd.
In het hier beschreven onderzoek wordt een epileptisch insult opgewekt, zodat het dier is verdoofd. Daarna wordt een lage stroom toegediend om de verdoving te handhaven tot en met verbloeden en de tonische en klonische krampen te onderdrukken.

Methode
Voor het bepalen van een correcte manier van verdoven zijn 38 vleeskuikens random geselecteerd uit koppels die aan de slachterij zijn geleverd. Kuikens werden individueel verdoofd door gedurende 1seconde een stroom van 275 door de kop te laten lopen. Deze inductie stroom werd direct gevolgd door een stroom van 60mA gedurende 3 seconden. Voor, tijdens en na het verdoven de hersen- en hartactiviteit geregistreerd voor het vaststellen van bewusteloosheid en hartfibrillatie. Na het verdoven zijn op vastgestelde tijdstippen pijnstimuli toegediend waarop het dier al dan niet (zichtbaar op het EEG) reageerde. Bloedingen in de spieren van de filets zijn visueel beoordeeld.

Resultaten
Op het EEG is een algemeen epileptiform insult met opeenvolgend een tonische-, klonische-, uitputtings- en herstelfase waargenomen na de stroomtoediening van 271 ± 32 mA gedurende 1 s gevolgd door een stroom van 64 ± 16 mA gedurende 3 s. Op basis van deze kenmerkende fasen op het EEG is vastgesteld dat deze dieren direct na stroom toediening bewusteloos zijn. Na gemiddeld 51 seconden keert het bewustzijn terug.
De meeste dieren reageerden op 60 s na de verdoving op de pijn prikkel. Volgens de correlatie dimensie score analyse blijven de kuikens in een staat van verminderde bewustzijn. Binnen een betrouwbaarheidsinterval van 95% en met in achtneming van het aantal dieren met een betrouwbaar EEG (n=26) is de kans op een effectieve verdoving van alle vleeskuikens tussen 0.9 en 1.0 met een ingestelde stroom van 275 mA gedurende 1 s gevolgd door een stroom van 60 mA gedurende 3 s.
In de filets zijn alleen enkele kleine bloedingen aangetroffen in de karkassen van de meeste dieren.

Conclusies
Vleeskuikens kunnen effectief worden verdoofd met de kop-kop methode met een elektrische stroom van 275 mA gedurende 1 s gevolgd door 60 mA gedurende 3 s.

Aanbeveling
Het wordt aanbevolen om de kop-kop verdover verder te ontwikkelen en deze praktijkrijp te maken zodat het apparaat zo spoedig mogelijk in commerciële slachthuizen kan worden geïmplementeerd.

Summary

Introduction
Current legislation demands that all birds are immediately rendered unconscious at stunning and that they remain insensible until death ensures. Use of the water bath is a legal electrical stunning method for poultry. Under practical conditions the presence of several birds at the same time in the water bath creates a parallel pathway of resistance. It has been claimed that under slaughterhouse conditions only about one third of birds are effectively stunned, while one third are inadequately stunned and the remaining third undergo cardiac arrest. The shackles and framework together with the bird itself form a conductive resistance to the current thus are potential sources of loss of electrical capacity. These sources of resistance are variable due to bird resistivity.
In order for a stun to conform to the demands of legislature several aspects of the water bath method are of importance to its successful execution. The legal minimal current for an individual bird in the water bath is 100 mA. Current Dutch and EU legislation on water bath stunning is incomplete and should include details concerning wave form and frequency alongside current levels in recognition of the large impedance variation between individual birds. The recommended minimum current for broilers in the EU increases quality defects (haemorrhages, broken bones) of carcasses and broiler meat. It is apparent that there can be a conflict between animal welfare and carcass quality using electrocution as stun-kill procedure. Therefore, the challenge still remains of providing an alternative stunning method with an effective threshold current that will induce consciousness and insensibility in broilers without compromising carcass quality.
The objective of the study was to evaluate behavioural, neural and physiological responses of broilers after head-only electrical stunning shackled by their feed.

Method
To asses a correct way to stun 38 broilers were used and obtained as they were delivered at the slaughterhouse from a commercial farm. Stunning was done one bird at the time.
The birds were hung at shackles with their legs and stunning was done electrically via pointed multiple electrodes on both sides of the head. Then the current ran through the head for 1 s with a set 275 mA followed by 3 s with a set 60 mA. The EEG and ECG were recorded from 30 s before and 5 minutes after stunning. The response of each animal to a noxious stimulus (comb pinching) was observed after stunning.
Hemorrhages in breast (dorsal side of *P. major* and *minor*) were visually quantified.

Results
On the EEG recordings a general epileptiform insult was observed when applying a measured current of 271 ± 32 mA for 1 s followed by a current of 64 ± 16 mA for 3 s were performed on 26 broilers weighing on average 2.4 ± 0.3 kg.This general epileptiform insult shows a tonic phase, followed by a clonic phase and an exhaustion phase, after which the birds remained drowsiness. These birds may have been unconscious for approximately 51 s. Also, according the correlation dimension score analyses they remain at a state of drowsiness. Within a confidence limit of 95%, taking into account the number of animals with a reliable EEG (n=26), the chance on an effective stun of all broilers lies between 0.9 and 1.0 with set currents of 275 for 1 s followed by 60 mA for 3 s is used. After stunning the ECG revealed fibrillation. The heart rate increased after stunning and recovered afterwards
When the birds were stunned and cut only spikes followed by a quiescient EEGs were observed.
Only minimal blood splashes were observed.

Conclusions
It can be concluded that broilers are effectively stunned with a controlled current of 271 ± 32 mA for 1 s followed by a current of 64 ± 16 mA for 3 s using a head-only stunner. Since the broilers may recover they should be neck cut as soon as possible after stunning to ensure that the bird remains unconscious.

Recommendation
It is recommended to develop this equipment further for practical implementation in broiler slaughter houses.

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1 Introduction

Various studies have shown that welfare at slaughter can be improved by sparing the animal's avoidable stress prior by prior application of effective stunning methods (Hindle et al., 2010). Stunning is a process that renders an animal unconscious without avoidable stress prior to killing/slaughter. A stunned animal should not recover until death occurs (Council Regulation, 2009). According to the EU Council Regulation (2009) 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. 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). Prior to application of stunning methods it is essential to confine or restrain the animal and to line up before the stunning itself.

Stunning by captive bolt was introduced towards the end of the 19th century, electrical stunning at the end of the 1920's and CO_2-gas stunning in the 1950's. Electrical stunning of poultry in a water bath has long been the common method in Europe (Raj, 2006).The water bath method is based on application of a current flow through the body of the bird which is suspended head-down by the legs in moving shackles. Thereafter, the birds pass through the bath in line. Depending on the dimensions of the bath several birds are submerged (up to their shoulders) simultaneously in water. Conventionally, a metal strip in the base of the water bath forms one electrode while the shackles are earthed and form the negative electrode, so that the electric current passes through the bird in the direction from head to legs. The water bath is electrically live so that each bird is stunned from the moment it makes contact with water (Bilgili, 1999, Fernandez, 2004) Essential to the success of electrical stunning of poultry are certain aspects which include adequate contact between bird and electrodes, level of current administered, duration of the stun (EFSA, 2004). The water bath is electrically live so that each bird is stunned from the moment it makes contact with water (Bilgili, 1999, Fernandez, 2004).

Under practical conditions the presence of several birds at the same time in the water bath creates a parallel pathway of resistance. It has been claimed that under slaughterhouse conditions only about one third of birds are effectively stunned, while one third are inadequately stunned and the remaining third undergo cardiac arrest (Woolley et al., 1986). The shackles and framework together with the bird itself form a conductive resistance to the current thus are potential sources of loss of electrical capacity. These sources of resistance are variable due to bird resistivity (skull bone structure and thickness (Woolley et al, 1986a, b), and shackle condition (degree of fouling, contact area with bird). These variations in resistance can influence the quality of the stun so that some birds receive too much while others receive insufficient current. Ultimately, this can lead to problems with either bird welfare (failure to lose consciousness or rapid recovery) or product quality (haemorrhaging, bone fractures) (Hindle et al, 2010).

An alternative to whole body electrical stunning is head-only stunning, where the stunning current passes only through the head of the animal. Head only stunning of broilers using 50 Hz, 117 V, corresponding to 336 mA per bird, appeared to be effective (Gregory & Wotton, 1990). In another study of Lambooij et al (2010) it was concluded that, broilers may be insensible and unconscious after head-only electrical stunning with pinned electrodes using an average current of 190 ± 30 mA (sinusoidal AC) for 0.5 s. For practical implementation a set current of 250 mA (average + 2*SD) is recommended to overcome individual differences in resistance. In this system the birds are shackled by their feet with their body in a cone-shaped restrainer and electrically stunned through the head. An alternative to this system is to shackle each bird and lift the head for head-only electrical stunning...

The objective of this study was to identify an electrical current and exposure duration to render broiler chickens unconscious instantaneously at slaughter using a head-only stunner. Stunning efficiency was assessed using behavioral observations and, EEG and ECG analyses...

2 Materials and Methods

2.1 Animals

Thirty-eight broilers delivered at the slaughterhouse from a commercial farm were used. Before transport the animals had a feed withdrawal period of 6 h and were transported in crates. During the experiment the birds were shackled one by one, the head lifted between spiked electrodes on both sides of the head and electrically stunned on using a controlled current stunner. (Figure 1) (Dutch Vision solutions BV, Zevenhuizen, Netherlands).

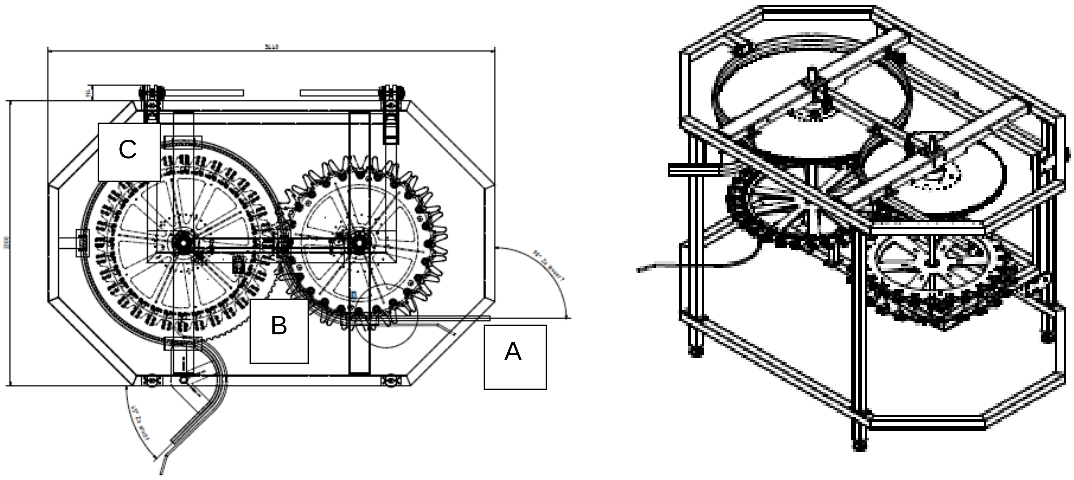

Figure 1 schematic design of the head-only stunner from above (left) and an overview. The broiler was shackled at point A, electrically stunned at point B and bled at point C.

The stunning current was delivered through the head for 4 s. Initially the current was relatively high for 1 s and was reduced to a lower value for 3 s (sinusoidal, 50 Hz). After the stunning experiment the broilers were weighed and breast and leg muscles were visually assessed for blood splashes (yes or no).

2.1 Experimental design

Prior to stunning each individual broiler was equipped with EEG and ECG electrodes. In order to facilitate the implantation of the electrodes, the broiler was hung individually by the feet at A in Figure 1. The EEG electrodes (10 mm long and 1.5 mm in diameter; 55% silver, 21% copper, 24% zinc) were placed by puncturing through the skin and skull: one electrode 0.3 cm to the right and one electrode 0.3 cm to the left of the sagittal suture and 0.5 cm of the imaginary transverse line at the caudal margin of the eyes. The ECG electrodes (35 mm long and 1.5 mm in diameter; same metal composition) were placed subcutaneously at the left and right side of the breast directly under the wing. The earth electrode for both the EEG and ECG was placed subcutaneously lateral at the thigh of the right leg. The EEG and ECG were recorded in the period from 30 s before and 2 minutes immediately after stunning. The response of each animal to a pain stimulus (comb pinching) was observed for 2 minutes following the stun in order to assess unconsciousness. The recorder used was a DI 720 data recording module with a WinDaq Waveform browser (Dataq Instruments, Akron, Ohio, USA).
Turning the carousel the 26 birds were moved individually to the stunning place at point B in Figure 1. The head was positioned between the pinned electrodes and the birds were stunned. They then moved on to point C in Figure 1 to be cut and bled. The birds were stunned between the electrodes using a set current of 275 mA (AC block, 50 Hz) for 1 s followed by a set current of 60 mA for 3 s. After recovery the birds were stunned again and bled.
Another 12 birds were handled according to the described procedure and bled as soon as possible after stunning.

2.2 Ethics

The experiments were approved beforehand by the Ethical Committee of the Animal Sciences Group of Wageningen UR.

2.3 Statistical analyses

The EEG traces were subjected to correlation dimension (CD) analysis. The CD analysis computes FFT and provides a non-linear (fractal) measure of signal complexity (for algorithm see Broek, 2003, Broek et al., 2005). The small amplitude, high frequency (awake) EEG signal is more complex than the large amplitude, low frequency (unconscious) EEG signal. Therefore, high CD values are taken to indicate awareness while low values indicate a state of unconsciousness. It is suggested that chickens are awake, drowsy and sleep at a CD score of 7, 6.6 and 6, respectively (Coenen and van den Broek, 2005). In poultry is suggested that a reduction in CD to 60% of the baseline value was an indicator of unconsciousness during gas stunning (McKeegan et al., 2007).
Each bird represents an experiment with a probability P that the bird is unconscious during a general epileptiform insult. For n birds, treated independently, the number x, which are unconscious, is binomially distributed with total n and probability P. A confidence interval can be calculated for probability P based on a relationship between the binomial and beta distribution. The number of effective stuns follows a binomial distribution. A 95% confidence limit on the probability for an effective stun can be obtained by means of a well-known relationship with the beta distribution (Johnson & Kotz, 1969).

3 Results

EEG and ECG recordings with a measured current of 271 ± 32 mA for 1 s followed by a current of 64 ± 16 mA for 3 s were performed on 26 broilers weighing on average 2.4 ± 0.3 kg. Immediately after stunning the birds displayed wing flapping for 4 ± 2 s. A general epileptiform insult with a tonic/clonic and exhaustion phase (Figure 2) was observed in all birds. The duration of the general epileptiform insult as visually scored on the EEG was on average 51 ± 12 s and 2 birds died. Five birds responded to the noxious stimulus 30 s after stunning, 19 birds after 60 s, 1 bird after 120 s and 1 bird did not respond at al.

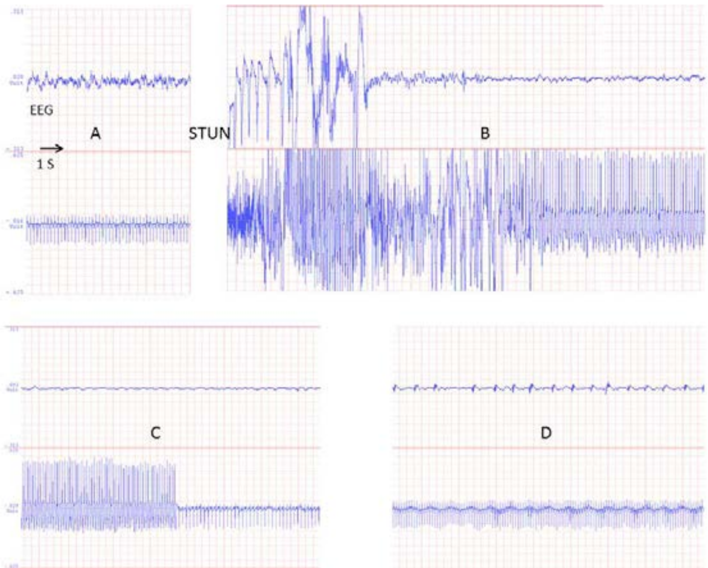

Figure 2 EEG and ECG recording before and after stunning. Prior to stunning a normal EEG and ECG rhythm can be observed (A). A general epileptiform insult characterized by irregular waves followed by waves with increased amplitude and decreased frequency and a period of strong depression on the EEG recordings and heart fibrillation (B). Followed by drowsiness (C after 30 s and after 120 s)...

According to the CD analyses of the EEGs it is considered that the birds may have been unconscious for approximately 20 s or longer assuming that a reduction in CD to 60% of the baseline value indicates unconsciousness. The birds became unconscious, recovered slightly and became drowsy again (Figure 3).
Within a confidence limit of 95%, taking into account the number of animals with a reliable EEG (n=26), the chance of an effective stun for all broilers lies between 0.9 and 1.0 when a set current of 275 mA for 1 s followed by a current of 60 mA for 3 s 100 mA was used.

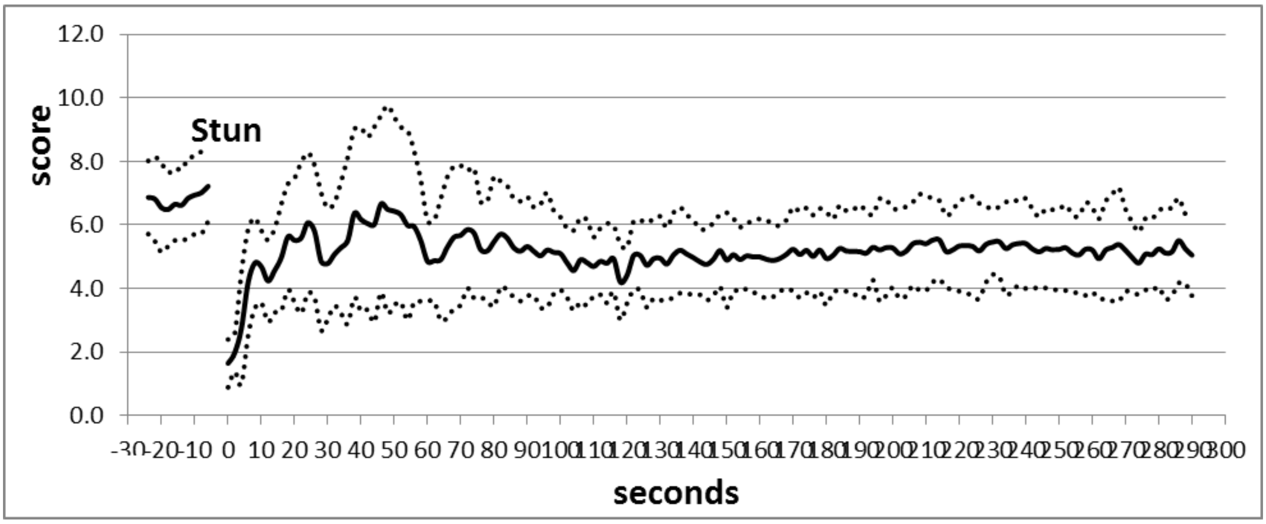

Figure 3 Correlation dimension analyses (Van den Broek, 2003) of EEG before and after electrical head-only stunning. The birds might be unconscious for approximately 20 s or longer assuming that a reduction in CD to 60% of the baseline value indicates unconsciousness.

The average heart rate prior to stunning with this method was 336 ± 57 beats/min. After stunning the ECG revealed fibrillation for 17± 6. Heart rate initially decreased to 272 ± 81 beats/min after stunning and recovered to higher values of 390 ± 68 beats/min after 2 minutes (Figure 4).

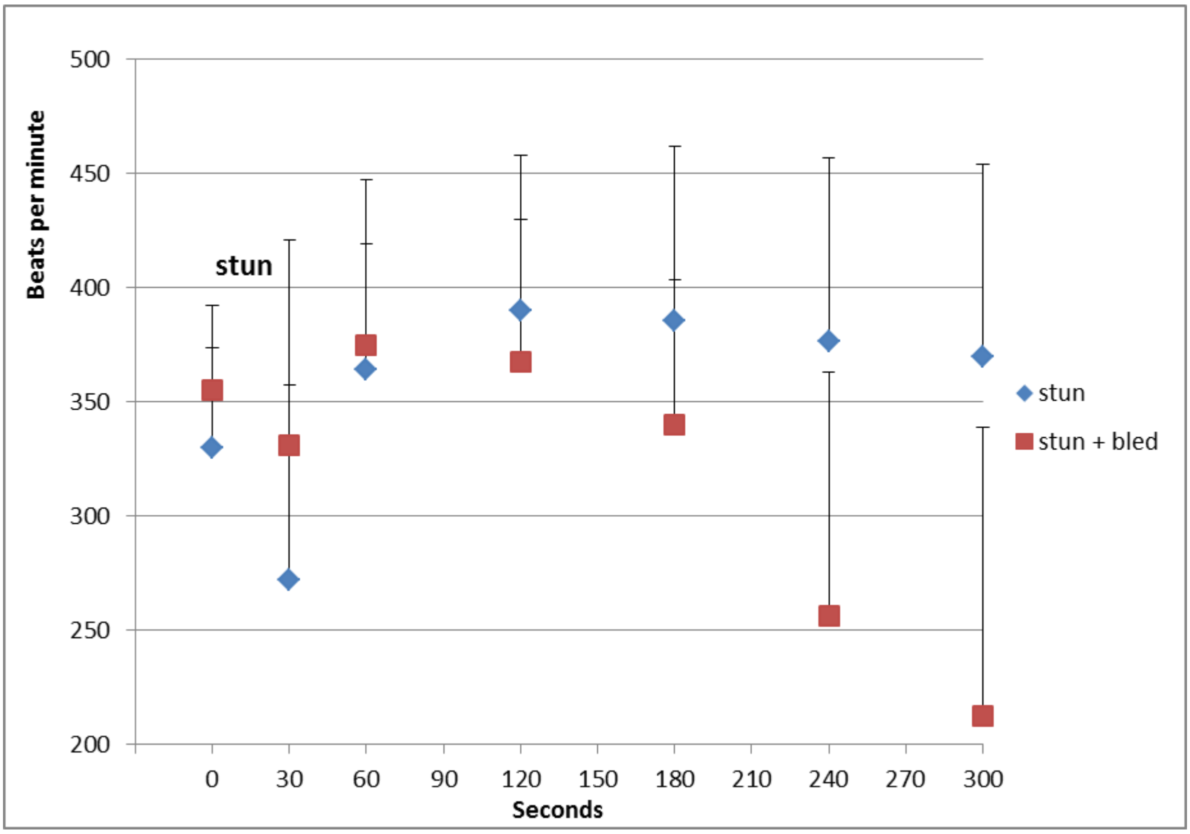

Figure 4 Heart rate (bpm) before and after head-only electrical stunning.

The measured current of the 12 birds bled immediately after stunning averaged 269 ± 47 mA for 1 s followed by a current of on average 58 ± 0 mA for 3 s. The average weight was 2.4 ± 0.4 kg. Neck cutting was performed in 17 ± 2 s after stunning. After stunning spike wave forms were observed for 46 ± 27 s on the EEG followed by quiescient EEGs. None birds responded to noxious stimuli. The average heart rate prior to stunning was 353 ± 21 beats/min. After stunning the heart rate increase to 382 ± 83 at 1 min and fell down to 158 ± 110 bpm at 5 min.

Minimal blood splashes in the major pectoralis muscle were observed in 21 out of 38 carcasses.

4 Discussion

Electro-stunning of animals is the passing of electric current through the skull of an animal. The stunning method is based in the induction of a general epileptiform insult (grand mal or seizure-like state). The epileptic process is characterised by rapid and extreme depolarization of the membrane potential. The brain is in a stimulated condition and unable to respond to stimuli (Lambooij, 2004). 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 (Lopes da Silva, 1983). Behavioural and clinical signs of recovery are not sufficient for the assessment of electro-narcosis, since the body is brought into tonic, clonic spams and exhaustion. Therefore, the use of EEG recordings alongside responses to stimuli (visual evoked response and somato-sensory evoked responses) to assess unconsciousness and insensitivity are recommended (Wageneder & Schuy, 1967). In the present study we used behavioural, noxious stimuli and EEG recordings. Moreover we used CD analyses which are a relatively new technique that has been customised to measure depth of anaesthesia in laboratory animals and humans (Broek, van den 2003). At present the analyses are also used in broilers, farmed fish and cattle (Lambooij et al 2010; Erikson et al, 2011; Lambooij et al, in press). The small amplitude, high frequency (awake) EEG signal is more complex than the large amplitude, low frequency (unconscious) EEG signal. Therefore, high CD values are taken to indicate awareness while low values indicate a state of unconsciousness. Earlier studies with chickens suggest that they were asleep at a score of 6 and during gas stunning a reduction in CD to 60% of the baseline value was seen as indication of an unconsciousness level similar to anaesthetized humans (Coenen & van den Broek, 2005; McKeegan et al., 2007). When these scores were used for electrical head-only stunning of broilers in an earlier experiment (Lambooij et al, 2010), the duration of insult was 12 to 18 s after stunning. Using the high-low head-only electrical stunning method the broilers remained in a reduced state of consciousness, which was also observed after stunning using transcranial magnetical stimulation (TMS) (Lambooij et al, 2011). As evidence of a profound effect of TMS on brain function, the birds showed a long lasting change in behavior seen as a loss of arousal or motor tone (muscle flaccidity). Using a lower power the birds became unconscious, recovered slightly and became drowsy again. On the basis of a visual score the duration of unconsciousness was scored at 51 ± 12 s after stunning, moreover most broilers responded at 60 s after a high-low electrical stun to a noxious stimulus.

Assessment of more parameters than general epileptiform insult and analgesia may support the humaneness of the stunning and killing system. EEG and neurotransmitter release measurements have been used to assess the effects of electrical head-only stun duration on welfare (Cook et al., 1992,1996; Lambooij, 2004). 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 state of unconsciousness Combining head-only stunning with exsanguination has a synergistic effect on the release of glutamate and aspartate, which increases the duration of unconsciousness (Cook, 1996). Sticking following a stun should be carried out as promptly as possible when using head-only stunning as it takes time depending on the species before brain responsiveness is lost following sticking (Anil, 1999; Hoenderken, 1978).). It is widely recognized 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 (Anil, 1991; Gregory, 1994; Wotton et al., 1992). When the birds were stunned and cut only spikes followed by a quiescience were observed on the EEGs when neck cut approximately 17 s after stunning in our experiment.

Hemorrhages can be induced by stunning, however, the underlying mechanism is considered to be multi factorial (Kranen et al., 1996). The validity of the present recommendations set at 100 mA for broilers stunned at a frequency of 50 Hz with the result that more than 67 % of the carcasses displayed blood splashes has been questioned (Hindle et al., 2010). Moreover, it became clear that using higher frequencies to reduce quality defects as blood splashes required higher currents to produce effective pre-slaughter stunning. When using head-only stunning only minimal blood splashes were observed in earlier (Lambooij et al, 2010) and the present experiment.

Conclusions

- It can be concluded from this experiment that broilers are effectively stunned with a controlled current of 271 ± 32 mA for 1 s followed by a current of 64 ± 16 mA for 3 s using a head-only stunner. Since the broilers may recover they should be neck cut as soon as possible after stunning to ensure that the birds don’t regain consciousness.

- There are only minor negative effects observed on meat quality expressed as low seriousness of blood splashes in fillets of carcasses.

- It is recommended to develop the equipment further for practical implementation in broiler slaughter houses.

Acknowledgement

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