Electrical stunning of broiler chickens

Simone Prinz

Dept. of Farm Animal Behaviour and Poultry Science, University of Hohenheim, Garbenstr. 17, D-70599 Stuttgart, Germany

* Correspondence: simone.prinz@gmx.de

Abbreviated title: Electrical stunning of broiler chickens

Summary

Electrical waterbath stunning is the most common method used in commercial slaughterhouses. After shackling the birds' heads are immersed into the electrified waterbath, causing the current to run through the head and body, thus inducing unconsciousness. Operating costs and space requirements are low. Depending on the electrical setup the animals can be stunned to kill, thus preventing recovery of the birds during bleeding. Cardiac arrest stunning has on the other hand been associated with meat quality defects due to convulsions. Application of high frequencies does not cause cardiac arrest, but insensibility of the broilers must be assured until death from bleeding. A variety of waveform and frequency combinations are used to achieve good stunning results while maintaining meat quality. With careful selection and operation of the electrical setup, electrical stunning provides the opportunity to maintain good welfare standards. Recent studies have shown that frequencies exceeding 400Hz cannot be recommended for a maximum current of 150 mA. The effectiveness of DC stunning has been discussed controversial. For effective DC stunning application time of the current seems to have a major influence. It has also been shown that due to a higher resistance, females obtain a lower current than males in constant voltage stunners, resulting in lower stunning effectiveness. Constant current stunners could solve this problem. As the different diameter of the females' legs is held responsible for the higher resistance, head-to-cloaca stunning has been investigated as alternative waterbath stunning method. Life shackling of broilers and the occurrence of pre-stun shocks cause welfare concerns. These issues should be addressed to further improve electrical stunning and thus animal welfare in commercial slaughterhouses.

Keywords: **Broiler, waterbath stunning, alternating current, direct current, electrical resistance, frequency, two-phase stunner, reflexes**

Background

At present, electrical waterbath stunning is the standard method used in commercial chicken slaughterhouses to render the birds unconscious. With this method, the birds' feet are fixed in grounded metal shackles. Hanging upside down, the birds are then moved towards an electrical waterbath. When the animals' heads touch the water the circuit is closed, causing the current to run through the head and body. This leads to a disruption of the depolarised state of the neurones in the brain and thus induces unconsciousness (Raj and Tserveni-Gousi, 2000). If the electrical current is too low for an immediate induction of unconsciousness, this may cause pain (von Wenzlawowicz and von Holleben, 2001).

Low frequency stunning

Several studies have been conducted to determine the minimum necessary current to render birds unconscious, using the electroencephalogram (EEG) and physical reflexes. Most of the recommendations are related to a sinusoidal AC waveform of 50 Hz. Results of Gregory and Wotton (1990) show that a minimum of 120 mA prevents recovery of somatosensory evoked potentials (SEP), indicating an unequivocal stun. In the same study a current of 105 mA provided a period of 52 seconds of apparent insensibility, judged by the return of neck tension. Application of 148 mA induces cardiac arrest in at least 99% of the animals (Gregory and Wotton, 1987). Wormuth et al. (1981) concluded that a minimum of 120 mA sine wave AC of 50 Hz causes cardiac fibrillation in 100% of the broilers. This was found to be the quickest method to induce brain failure (Gregory, 1989).

Implications for meat quality

Application of high currents on the other hand causes a number of meat quality defects. Gregory and Wilkins (1989) found an increase of breast muscle haemorrhages in broilers stunned with currents higher than 130 mA. Hillebrand et al. (1995) found similar effects in broilers stunned with 100 mA. A high voltage level has been associated with a lower bleed-out (Veerkamp and de Vries, 1983). Red wing tips could be observed with a 50 Hz sine wave AC above 110 mA (Gregory and Wilkins, 1989). In addition, the occurrence of broken wish bones increases with higher voltage levels (Gregory and Wilkins, 1990). Electrical setups have therefore been sought that prevent meat quality defects. This has mainly been achieved by altering the frequency and waveforms of the current. Raj et al. (2001) found a significantly lower occurrence of broken bones and breast meat haemorrhages in broilers stunned with a sine wave AC of 1500 Hz compared to 50 Hz. Gregory et al. (1991) on the other hand could not find a difference in the occurrence of haemorrhages in broilers stunned with 50 or 350 Hz pulsed DC. The incidence of ventricular fibrillation however, was markedly decreased with the higher frequency. It has been shown that pulsed DC stunning has a lower effect on heart function and results in overall better bleed-out (Kuenzel and Ingling, 1977).

Stunning effectiveness of high frequencies

If stunning setups do not induce ventricular fibrillation, it must be assured that the birds remain unconscious until death from bleeding. A minimum of 40 seconds unconsciousness has therefore been suggested (Raj, 2006). Based on the absence of SEPs, a minimum of 120 mA pulsed DC of 350 Hz has been recommended to achieve effective stunning (Gregory and Wotton, 1991). Several investigations have been conducted on different waveforms and frequencies (Wilkins et al., 1998; Wotton and Wilkins 1999) but only physical parameters such as breathing and neck muscle tension were assessed (von Wenzlawowicz and von Holleben, 2001). The reliability of these physical parameters for the assessment of unconsciousness is not well established.

Latest research

In more recent studies, the effectiveness of AC and DC stunning has been analysed using quantitative EEG analysis rather than subjective assessment of brain waves. This provides a better description of the degree of changes in the power content of EEG signals, hence more reliable information on the state of (un)consciousness (Raj and O'Callaghan, 2004a). Based on these criteria, it has been concluded that effective waterbath stunning can be achieved with a sine wave AC of 100, 150 and 200 mA root mean square with maximum frequencies of up to 200, 600 and 800 Hz respectively (Raj et al., 2006a). The acceptability of pulsed DC stunning on the other hand has been questioned, as some broilers obtained cardiac arrest without expressing epileptic activity in the EEG (Raj et al., 2006b,c). Prinz (2009) has analysed the effect of a wide range of current and frequency combinations on the occurrence of an iso-electric EEG following waterbath stunning of broilers using a non-invasive EEG technique (Coenen et al., 2007). In this study, stunning frequency had the main impact on the induction of unconsciousness, and frequencies exceeding 400 Hz did not prove to be effective with the highest tested stunning current of 150 mA (Prinz et al., 2009). In contrast to Raj et al. (2006b,c) application of a pulsed DC was equally effective to AC treatments. It was concluded that the minimum acceptable current is 100 mA and 80 mA for AC and DC respectively in combination with a maximum of 200 Hz. With frequencies ranging from 200 to 400 Hz, the current level must be increased to at least 120 mA and 150 mA for AC and DC respectively (Prinz, 2009; Prinz et al., 2009). It has been discussed that the different effectiveness of DC stunning in the two studies might be due to the different application time of the current. While in the study of Raj (2006b,c) DC was not effective after 1 second stunning time, current application of 10 seconds achieved good results (Prinz, 2009). A shorter stunning duration of 4 seconds on the other hand was less effective (Prinz, 2009).

Challenges of constant voltage stunning

Under practical conditions, birds are stunned in multi bird waterbaths. In the European Union, both AC and DC waveforms are applied with frequencies ranging from 50 Hz to 2000 Hz. The average current per bird is usually set between 70 mA and 150 mA in European slaughter plants, but due to the individual impedance of the animals the actual level varies. In constant voltage waterbaths, the animals form parallel circuits and the actual current per bird is thus determined by the individual resistance. This leads to variation in effective current with a potential effect on stunning efficiency and meat quality. It has moreover been discussed that females have a higher electrical resistance compared to male broilers (Rawles et al., 1995). This was confirmed by Prinz (2009), who additionally analysed the effect of the higher resistance on stunning efficiency. For female birds an increase of 20V compared to males was necessary to obtain the same effective current and induce unconsciousness. Constant current stunners could solve this problem. It has been suggested that the smaller diameter of the female legs, resulting in a weaker contact with the shackle, cause the different electrical impedance (Prinz, 2009). To overcome this problem, Lambooij et al. (2008) analysed an alternative method of waterbath stunning, where a steel electrode penetrating or around the cloaca formed the second electrode. Application of 50V sine wave AC of 640 Hz resulted in an average current of 111 mA, which was sufficient to render the broilers unconscious when applied for 1 second. Hindle et al. (2009) came to the same conclusion. In addition they analysed the effectiveness of alternative waveforms with modified square wave alternating currents consisting of several brief pulses. Epileptiform activity could be observed in the EEG, but the authors concluded that this method could not be recommended to solve the problem of blood splashes due to the necessary high current (Hindle et al., 2009).

Electrical stunning in two phases

In the U.S. current levels are considerably lower (25 to 45 mA) compared to the EU (Bilgili, 1999). A step-up stunner (Simmons Engineering Company, Dallas, GA, USA) has been introduced, consisting of two consecutive stunning phases. In Phase I a pulsed DC of 550 Hz is applied with a low voltage of 12-15 V in a shallow brine waterbath. The water depth is approximately 1 cm, with the chickens' head resting on a metal grid. This is immediately followed by Phase II, consisting of a metal plate. In Phase II a sine wave AC of 50 Hz is applied with 20-40 V. In the first phase, chickens are rendered unconscious and the body is relaxed, while the second phase induces a deeper stun. This stunning system is now also used in the European Union, but stunning effectiveness of the low currents has been questioned (Raj, 2003). The low voltage in Phase I resulted in adequate stunning effectiveness, judged by the return of rhythmic breathing and tension of the neck muscle (Wotton and Wilkins, 1999). Coenen (2009, personal communication) determined a minimum stunning current of 20 mA in Phase I to induce a generally deranged EEG for a short period post-stun, which can be associated with unconsciousness. Prinz (2009) analysed the effectiveness of both stunning phases using EEG analysis. Phase II showed the biggest impact on stunning efficiency, but the maximum tested voltage of 60V did not achieve adequate unconsciousness. However, while the EEG indicated possible sensibility, the animals failed to express physical reflexes. Assessment of behavioural parameters to assess stunning efficiency can therefore be misleading (Prinz, 2009). The absence of convulsions however indicated possible meat quality advantages, and higher voltage settings should therefore be considered to assure good animal welfare standards.

Conclusions

Currently, the acceptance of electrical waterbath stunning is widely discussed. With regard to space and financial resources, it offers some unique advantages. Depending on the individual setup, birds can be reversibly or irreversibly stunned. However, some issues must be addressed to ensure good animal welfare and optimise meat quality. Further research is therefore necessary to better understand the influence of the electrical parameters on the body tissues of broilers.

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