Why poultry should be stunned at slaughter and the welfare advantages and challenges of electrical and gas stunning

R.J. Buhr

USDA-ARS Russell Research Center, P.O. Box 5677, Athens, GA, 30604-5677, USA

Correspondence: jeff.buhr@ars.usda.gov

Abbreviated title: Stunning of poultry for slaughter

Summary

Poultry are stunned immediately prior to slaughter to facilitate automated processing, to minimize the subsequent death struggle and thereby minimize carcass damage and down grades, and to render the bird unconscious and incapable of perceiving pain. A stunning method for slaughter should be considered ethical if the following criteria are attained. 1) Stunning results in a rapid onset of unconsciousness within a minimal time and with a minimal perception of pain. 2) The duration of the stun induced unconsciousness persists until death intervenes. 3) There is a near zero occurrence of "under stunned" and unstunned individuals. Stunning by definition must permit the stunned animals to recover consciousness. Electrically stunned broilers should recover consciousness to the level of regaining the ability to maintain an erect posture within 120 seconds following the stun. However, electrical stunning and exsanguination (bleeding) are integral steps in the slaughter of poultry and should be evaluated together in the progression to death. In contrast, poultry subjected to electrocution or gas stunning protocols are characterized as stun-kill because by design these birds will not regain consciousness at any time point even in the absence of exsanguination. There are distinct advantages and challenges to both electrical and gas stunning protocols which will be described and discussed.

Keywords: electrical stunning, controlled atmosphere stun/kill, unconsciousness, poultry processing

Appraisal of the Stunning Poultry at Slaughter

The use of electrical current to stun poultry dates to 1749 when Ben Franklin demonstrated that turkeys killed with electricity had the pleasant side-effect of making the meat uncommonly tender. This was reportedly the first practical application that had been found for electricity (Lopez and Herbert, 1975). Commercial application of electrical stunning of poultry immediately prior to slaughter was initiated in the 1950's to facilitate automated bleeding and faster processing line speeds (Fletcher, 1999). Electrical stunning minimizes the ensuing death struggle that occurs during exsanguination and the associated carcass damage for broilers suspended from shackle lines during bleeding. Previously, poultry were placed into bleeding cones during exsanguination where carcass damage was minimal, and shackling occurred after the completion of bleed-out. During the 1990's the necessity for stunning poultry to render them unconscious and incapable to perceive pain through death became a humane animal handling priority. Carbon dioxide gas stunning had been evaluated for poultry in the 1950's with reevaluation with inert and mixed gases during the 1990's. Stunning poultry mechanically by concussion, as used for the slaughter of large animals, or by brain sticking, is not commercially utilized in present day processing plants (Lambooij *et al*., 1999).

A stunning method would be considered ethical if the following criteria were attained. 1) Stunning resulted in a rapid onset of unconsciousness within a minimal time and with a minimal perception of pain by the individual animal. 2) The duration of the unconsciousness persisted until death intervenes. 3) There is a near zero occurrence of "under stunned" or unstunned individuals. Guedel in 1937 was the first to designate four stages of anesthesia from consciousness through unconsciousness, to death, and the association with the perception of pain, Table 1 (Guedel, 1937; ACVA, 1995). At Stage 2 and higher, the individual is determined to be unconscious and therefore unable to perceive pain, however skeletal muscle reflexes (including ventilation) and cardiac function persist.

Table 1. Stages and signs of anesthesia, modified from Guedel, 1937

Stage 1.	Analgesia - may be local or general. Local loss of pain sensation, some disorientation or numbness, subjects remain conscious, voluntary muscle movements.
Stage 2.	Unconscious - delirium, epileptiform brain activity (human grand mal seizure). Loss of the ability to perceive pain, muscle reflexes are present, involuntary struggling may occur, accelerated ventilation rate.
Stage 3.	Surgical anesthesia 3-planes
	Light - Skeletal muscle relaxation but reflexes are present, no voluntary muscle movement, regular ventilation rate, palpebral and corneal reflexes present.
	Medium - Skeletal muscle reflexes absent, palpebral reflex absent, and corneal reflex sluggish.
	Deep - Early overdose, ventilation depressed (forced ventilation required) and corneal reflex absent.
Stage 4.	Overdose and death - brain stem paralysis and flat line EEG (<10 μV). Cranial nerve reflexes absent, no initiation of respiration, and cardiac function present but depressed.

The term electric anesthesia is defined as anesthesia induced from the passage of an electric current through the central nervous system (brain and spinal cord). This is analogous to electrical stunning and corresponds to an unconsciousness level approximating Stage 3 between Light and Medium. Electrical stunning induces unconsciousness in poultry, but how can one determine the level of unconsciousness and therefore the inability of the broiler to perceive a pain stimuli? To answer this question, the relationships of unconsciousness level and the ability to perceive pain need to be further evaluated and confirmed. Electroencephalograms (EEGs) are recordings of brain waves that measure the electrical activity of the brain and are very temporally precise. EEGs from brain implanted electrodes have been used to determine the level of consciousness and muscular activity of subjects, including broilers (Kuenzel and Walther, 1978; VanKampen *et al*., 1979). Some reports have suggested that unconsciousness is attained when EEG activity is suppressed to 60% of resting level (McKeegan *et al*., 2007) and that functional brain death is attained when EEG activity is suppressed to <10μV (10% of resting level) and the EEG shows no rhythms or response to evoked potentials (Schwab *et al.*, 1963). Delineated levels of unconsciousness in poultry resulting from administered anesthetics and direct comparisons to various commercial stunning methods have not been reported.

Adequately electrically stunned broilers should recover consciousness, to the level of regaining the ability to maintain an erect posture, within 120 seconds following the stun. However, electrical stunning and exsanguination (bleeding) are integral steps in the slaughter of poultry and should be evaluated together in the progression to death when comparing alternatives and modifications to stunning and slaughter methods.

The American Veterinary Medical Association guidelines on euthanasia (AVMA, 2007) describes three physical methods for euthanasia appropriate for poultry: 1) electrical stunning with an apparatus that assures passage of the current through the brain followed immediately by a method that ensures death such as exsanguination, decapitation, or electrocution; 2) cervical dislocation by trained personnel, and 3) electrocution if the animal is first rendered unconscious by stunning. When cervical dislocation or decapitation is preceded by electrical stunning, there is no death struggle, which typically occurs with cervical dislocation without prior stunning. It is important to remember that the basis for euthanasia of individual animals differ from stunning of animals for slaughter, and euthanasia of flocks of animals for depopulation to halt the spread of epidemic diseases; and therefore the recommend guidelines may not be interchangeable.

Historically the level of unconsciousness and the associated inability to perceive pain has been evaluated in stunned poultry by the absence of the palpebral (eyelid) avoidance reflex or the absence of the limb withdrawal reflex when a distal toe pinch was applied. These methods can not be practically applied or observed on shackle lines operating at speeds as high as 140 birds per minute and bird spaced at 15.24 cm (6 in) intervals. Recently we confirmed that spinal cord severing of stunned broilers on line and not inducing a death struggle could be used as an indication of unconsciousness (Buhr unpublished data). Electrically stunned broilers (25 V DC at 500 Hz, for 8 seconds in a brine stunner) were bled by severing both carotid arteries and the right jugular vein and then at 30-second intervals spinal cord severing was applied from 30 through 120 seconds. Spinal cord severing applied to the stunned and bleeding broiler carcasses resulted in no subsequent death struggle. Therefore, electrical stunning followed by bleeding appeared to maintain unconsciousness through the duration of the 120 second bleed out period and death. Additional experiments have revealed that electrical stunning durations as short as 2 seconds result in unconsciousness sufficient that immediate spinal cord severing did not result in a subsequent death struggle. These results suggest that the onset of unconsciousness by the application of electrical stunning is indeed rapid (Wotton and Wilkins, 1999) and when accompanied with bleeding, unconsciousness is maintained until death occurs within 120 seconds of bleed-out.

Skeletal muscle activity (wing flapping or ventilation) during bleeding is not necessarily an indication that the broiler is regaining consciousness since reflex skeletal movements do occur during Stages 2 and Stage 3-Light anesthesia, while the ability to perceive pain remains absent. Similarly, the occurrence of a cadaver indicates that a functional brain stem and cardiovascular system were present at the time the brain perceived an elevation in body temperature upon entering the scalder water. Two studies have concluded that "red-skin" cadaver chicken carcasses are caused by the physiological response to elevated temperatures when carcasses enter the scald tank (Heath, *et al*., 1983; Griffiths and Purcell, 1984). Unconscious broilers at Stage 3-Medium level of anesthesia (ideal for deep tissue surgery) with a functional brain stem (reflex ventilation present) would, upon entering the scalder, result in cadavers. Therefore, the presence of skeletal muscle movements during bleeding, and cadavers upon scalding, can occur as long as the broiler's brain stem is functional, but at a level of unconsciousness that pain is not perceived. The goal to further minimize the occurrence of skeletal movements during bleeding and cadavers can be achieved by the addition of decapitation or spinal cord severing following stunning, during bleeding (McNeal *et al*., 2003; Buhr *et al*., 2005). However, the elimination of the physiological potential for cadavers in processing plants that utilize post-stun decapitation does not eliminate the continued classification of defeathered carcasses as cadavers. The classification of cadavers includes "all carcasses that died by any method other than exsanguination" which would include those that died prior to stunning. In a United States plant that utilized post-stun decapitation the prevalence of carcasses classified as cadavers decreased by only 0.0071 percentage point, from 0.0464% (prior to implementation of decapitation) to 0.0396% with the implementation of decapitation. Therefore, the poultry processing industry needs to refine the terminology to distinguish between true cadavers and all others.

Electrical Stunning Versus Stun/Kill:

Typically in the United States, commercial electrical stunning is applied at low amperage of 12 to 24 mA for 7 to 12 seconds using high frequency pulse (500 Hz) direct current. However, commercial stunning systems do vary in current form (alternating or direct), low to high frequency (50 to 500 Hz), sine or rectangular wave form, half or full rectified alternating current (to direct current), and may be applied as constant or pulsed currents (Bilgili, 1992). The electrical stun-kill systems commonly used in the European Union use current levels from 100 to 125 mA, for a shorter duration of 4 to 6 seconds, at a lower frequency 50 to 60 Hz, and are typically alternating current. Stun-kill or electrocution systems induce ventricular fibrillation and cardiac arrest resulting in the cessation of blood flow causing anoxia in the brain and death rapidly supervenes with or without exsanguination.

Controlled Atmosphere Stunning (CAS):

Controlled atmosphere stunning systems typically deplete oxygen (hypoxia) resulting in elevated levels of carbon dioxide in the respiratory tract and circulating blood. Hypoxia can be attained by subjecting poultry to a single gas such as carbon dioxide, nitrogen or argon, or a combination of gasses with or without the addition of low levels of oxygen. CAS can be either a single chamber or multiple chambers in series with increasing gas concentrations from an initial concentration of 30% proceeding to 70-100% and the associated corresponding decreasing oxygen concentrations. The inclusion of low levels of oxygen significantly delays the onset of unconsciousness and death. However, oxygen lacking atmospheres result in a more rapid onset of death, but more severe wing flapping during the death struggle resulting in carcass damage. The induction of the death struggle occurs at a period that consciousness cannot fully be excluded or determined by EEGs due to electrical interference from muscle contractions. Therefore, it has been suggested that a gas mix with oxygen may be preferable to a gas mix without oxygen. The presence of oxygen in the first stage of stunning is important in the depression of distress, resulting in a milder death struggle, which takes longer, but may be preferable to a quicker and more distressing death.

Hypoxia can also be obtained by air removal during the creation of a vacuum lowering atmospheric pressure to 0.2 atm (19.4 kPa) in a sealed container (Purswell *et al*., 2007). Low atmosphere stunning (LAS) reportedly provides many of the advantages of CAS systems (stunning in transport modules and poststun shackling) without the additional expense to purchase and store the gas. CAS and LAS stun exposure durations typically range from 90 to 250 seconds. The two commonly used commercially methods to stun poultry, electrical and controlled atmosphere, have distinct advantages and challenges for improvement in animal welfare, Table 2.

Table 2. Contrast of electrical and controlled atmosphere stunning for poultry welfare advantages and challenges

Electrical Stunning Advantages:
Provides rapid onset of unconsciousness, < 2 seconds
Relatively inexpensive to operate and to configure to plant space specifications
Electrical Stunning Challenges:
Shackling of conscious poultry prior to stunning
Potential for prestun shock
Potential for electro-immobilization versus unconscious
Controlled Atmosphere Stunning Advantages:
Provides for stunning of poultry in transport modules
Provides for shackling of post-stun unconscious poultry
Controlled Atmosphere Stunning Challenges:
Unconsciousness is not rapid and additional expense of purchasing and storage of gas
Requires rapid detection of carcasses that died during transport prior to stunning
Potential for consciousness at loss of posture and the initiation of the death struggle

The main challenges for electrical stunning systems are shackling of conscious animals, prestun shock, and the potential for electrical immobilization. The development of pliable shackles to accommodate the range in hock widths for both genders is desirable for equipment optimization and minimization of carcass contamination regardless for stunning method. Pliable shackles would minimize the resistance due to poor contact between the shanks and the shackle resulting in greater uniformity in the current level received by each bird. The potential for prestun shock has been diminished by redesign of the in-feed ramp above the brine stunner solution (Bilgili, 1999). The possibility of the occurrence of electrical immobilization (retaining the ability to sense and perceive pain but unable to respond to stimuli) can occur if the electrical current path of the stun does not reach the brain of the subject. Electrical immobilization does not appear to occur in electrically stunned broilers (using a brine stunner) head to feet, since spinal cord severing following stunning and bleeding does not result in a death struggle. The limitations of brine

stunners and the potential presence of electrical immobilization could be addressed by EEGs and should be evaluated under various stunning parameters.

The main challenges for CAS are the prolonged onset of unconsciousness and death. The status of CAS poultry at the time of loss of posture and the onset of the death struggle requires confirmation of the stage of unconsciousness through the use of EEGs and telemetry and the duration for the potential to perceive pain documentation. Thermal imaging and tracking at shackling can be used to identify carcasses presumed to have died prior to stunning. The use of LAS without the need to purchase or store gases many provide economical savings in the future.

The determination of the ethical status of stunning and slaughter methods depends greatly on a critical review of the literature and that the results and conclusions agree with the published literature and the present body of knowledge of physiology and anatomy. There are frequent misconceptions associated with processing that are repeated in support of or used to criticize other methods of stunning and slaughter. The following are examples of some slaughter misconceptions that should not be continued.

Is a beating heart needed for carcass bleed-out blood loss? All comparative studies among slaughter methods utilizing various stunning and bleed-out protocols have resulted in minimal detectable difference in the quantity of blood retained within muscle tissue of a fully processed and chilled carcass. This is mainly determined by the fact that only 50% of the total blood volume of the animal (6.6% of body weight) is removed during processing and the remaining 50% is retained within the blood capillary system and can only be removed by vascular perfusion with liquid or air. It is important to acknowledge that the heart functions as a pump and only resupplies blood to the lungs and body in the exact quantity that blood is returned to the heart through the venous system. During exsanguination following severing of a jugular vein in the neck, blood exits the carcass and is no longer available for the heart to pump to either the lungs or the body. Therefore, a pumping heart is not necessary for bleed-out blood loss and adequate blood loss can be obtained from a carcass with a heart in fibrillation or that no longer beats.

Does stunning reduced feather retention force? Buhr *et al*. (1997a) sampled the left and right carcass side feather tracts before and following stunning (electrical and carbon dioxide) and detected nonsignificant

differences, clearly demonstrating that stunning does not influence feather retentions force. Further investigations utilizing cutaneous nerve transsection determined that the peripheral nervous system exhibited no discernable influence on feather retention force ante- or postmortem (Buhr *et al*., 1997b).

Does carbon dioxide gas have anesthetic properties in poultry? There are no published results indicating that carbon dioxide in any stunning protocol for poultry provides anesthetic or analgesic properties. Furthermore, the occurrence of loss of posture can not be equated with a state of unconsciousness.

In summary, we need to determine if the definition of unconsciousness in poultry at 60% of resting EEG activity levels and functional brain death at 10% of resting EEG activity levels can achieve confirmation and validation. Once confirmed, these EEG standards can then be utilized to optimize both electrical and gas stunning protocols, to assure and monitor unconsciousness in stunned poultry until death, for humane slaughter.

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