

Technical parameters of electrical stunning and their impact on broiler meat quality: a review

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Abstract

Electrical stunning has shown a positive effect on meat quality parameters and animal welfare during slaughter compared to unstunned animals. However, these influences are related to the used values of technical parameters, which may vary depending on the country or specific slaughterhouses. The use of electric stunning method has also faced criticism from some welfare researchers and organizations, who often consider this method of stunning as insufficient from an animal welfare perspective. The aim of this study is to review the influence of different technical parameters of electrical stunning on the meat quality of broilers, as well as on animal welfare during the stunning and slaughter process.

Keywords: *Meat quality, chicken meat, water bath stunning, welfare*

Introduction

Electrical stunning is a commonly utilized prior to neck cutting to induce unconsciousness thereby improving both animal welfare and slaughter efficiency in the broiler production industry (Li et al. 2022). The obligation to stun farm animals is based on European regulations, which require that animals, including poultry, are immediately stunned rendering them unconscious and insensible until death occurs through blood loss at slaughter, thereby protecting them from avoidable pain, fear, stress, and excessive distress. If the birds are not stunned before exsanguination, convulsions will occur as they struggle for life, which would cause damage to the bodies such as broken wings or collarbones (Bourassa et al. 2017; Hindle et al. 2010). As stunning can generally minimize the pain and suffering associated with slaughter, it has been viewed positively from an animal welfare perspective. However, inconsistencies in standardization of technical parameters, along with variations in previous research outcomes, have led to numerous cases of under-stunned and over-stunned birds (Hayat et al. 2024). The effects of electrical stunning on the final quality of the meat also depend on the voltage, frequencies and duration used. In general, the duration of unconsciousness increases with higher stunning voltage, but this also aggravates carcass damage (Huang et al. 2014). The use of electric stunning in a water bath for poultry slaughter has drawn criticism from some animal welfare researchers and organizations worldwide (Fuseini et al. 2018). Concerns about the pain and stress of farm animals when slaughtered for human consumption are also recognized by consumers, who are aware of the connection between welfare during slaughter and meat quality (Hayat et al. 2023). It is generally agreed that electric water bath stunning may result in poor meat quality due to muscle contractions and fractures, especially when higher currents are used. While this is not considered an animal welfare problem, it may lead to staff lowering the required stunning parameters in order to improve meat quality and thus worsening animal welfare. Nevertheless, electrical water bath stunning is likely to continue for economic and commercial reasons (Berg a Raj 2015).

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Electrical stunning of broilers

After being shackled on an overhead conveyer, the poultry move toward an electrified water bath, where their heads make contact with the electrically charged water (Shields a Raj 2010). Unconsciousness is induced due to the passage of an electric current through the central nervous system. This process commonly involves submerging multiple birds at the same time, which can lead to varying stunning results. Individual birds differ in many ways, and the effectiveness of stunning depends on several factors such as the size of the bird, muscle and fat content, gender or the state of the feathers (wet or dry). These differences may affect the effectiveness of constant voltage stunning, and individual birds may receive more or less electrical current than expected (Girasole et al. 2016). Electrocution can also cause death due to ventricular fibrillation, which may be associated with an increased incidence of carcass damage such as red wingtips or haemorrhage. In commercial settings, it is also difficult to distinguish bruises caused by electrical stunning from other factors such as hanging and twitching (Novoa et al. 2019). The problems associated with the electrical stunning of poultry in a water bath are also complicated by the fact that a large number of current levels (Amps), wavelengths (DC and AC) and frequencies (Hz) are used commercially. In addition, it has been questioned whether the highest frequencies will result in effective stunning, as the birds may still appear paralyzed and therefore it may be difficult to identify bad stunned birds. (Berg and Raj 2015). However, pre-slaughter electrical stunning has been shown to reduce meat PSE, which is related to pH values and stress, to which animals are exposed during slaughter without stunning (Kissel et al. 2015). Regulation (EC) No. 1099/2009 on the protection of animals at the time of killing established minimum values of the electric current passing through an individual animal at a specified frequency in order to ensure effective stunning, which must last until the animal is killed (Sirri et al. 2017). The animals must be exposed to these values for at least four seconds (Council regulation (EC) No. 1099/2009). Combinations of electric parameters for chickens from regulation (EC) No. 1099/2009, as well as other methods are shown in Table 1. In the European Union, the most common values used for stunning are 120 mA, which causes cardiac arrest in 90% of poultry, thus achieving immediate and irreversible stunning, which means that the animals are not exposed to stress (Kissel et al. 2015). In the United States, around 90 % of slaughterhouses use electrical stunning, of which about 65% use a low current for stunning broilers (Shafik et al. 2021). Low voltage (10 to 25 V) and high frequency (500 Hz) systems are used, which achieves immobilization of poultry with minimal damage to the carcass (Kissel et al. 2015). The medium voltage (medium current) with low frequency is most often used in China (Huang et al. 2014). however, some countries, especially countries of the Middle East (Saudi Arabia, UAE, Israel) can also use slaughter systems without stunning for religious reasons, specifically halal by Muslims and kosher by Jews (Farouk et al. 2014).

Technical parameters of electric stunning and their effect on meat quality of broilers

Some studies show lower efficiency of electric stunning in broilers, which is associated with greater stress in the animals (Silva-Buzanello et al., 2018). In a study by Bourassa et al. (2017), the ability to regain consciousness in relation to the length of stunning (60, 90 and 120 seconds) in both sexes of broilers after direct conduction stunning at 15 and 25 V was investigated. In the 60 second stunning using 15 and 25 V, they recorded 75% and 50 respectively % regaining consciousness with a significant difference in gender where when using 25 V, 82% of females were able to regain consciousness compared to 23% of males. When stunned for 90 seconds (15 and 25 V), only 17% and 4% of broilers regained consciousness. The stunning time required to prevent recovery of consciousness in 100%

Table 1. Methods of electric stunning and their effect on meat quality and welfare of broilers

Region	Methods	Used parameters	Positive	Negative
Europe ^a	high voltage (High current) with low frequency ^a	100 mA, < 200 Hz ^b	increasing the duration of the stun ^h ,	strong contractions,
		150 mA, 200-400 Hz ^b	least stressful ^d	broken bones ^d ,
		200 mA, 400-1500 Hz ^b		red wing tips ^d
China ^a	medium voltage (medium current) with low frequency ^a	50 V, 48-52 mA, 50 Hz ^c	improving the physical properties (pH, drip loss, cooking loss) ^c	most stressful electrical parameters for broilers ^g
USA ^a	low voltage (low current) with high frequency ^a	10-25 V, 500 Hz ^d	improving the quality of carcasses ^a	shorter stun effect, welfare ^h
Middle east ^e	slaughter without stunning ^e	-	religious reasons (halal, kosher) ^e	Welfare, stressful, higher incidence of PSE ^d , hemorrhages ^e

^aHuang et al. (2014), ^bRegulation (EC) No. 1099/2009, ^cLi et al. (2022), ^dKissel et al. (2015), ^eFarouk et al. (2014), ^fShafik et al. (2021), ^gXu et al. (2011), ^hSmaldone et al. (2021)

of the broilers was 120 seconds for both voltage values. Changes in carcasses such as broken bones, bleeding and blood accumulation are related to high electrical intensity as well as to hanging and handling conscious poultry (Silva-Buzanello et al. 2018). Slaughterhouses are increasingly focusing on meat quality, primarily on improving water retention in meat and thus higher yields (Huang et al. 2017). In a study by Gezgin and Karakaya (2016), when comparing a group of electrocuted broilers with a non-stunned group, a higher water retention capacity was noted in the electrocuted group. Older studies have also shown voltage differences on the water retention capacity of meat, where medium voltage stunning (50 V, 50 Hz) was shown to decrease this capacity compared to low voltage (15 V, 750 Hz) as well as high voltage stunning. (100V, 50Hz). This is also confirmed by the results of the study by Huang et al. (2014), which reported the lowest water retention capacity in the sample stunned by the low frequency medium voltage method compared to the low frequency high voltage and high frequency low voltage methods. The method of medium voltage also proved to be the most stressful. A study by Xu et al. (2011) also confirms that medium level current (50V, 67 mA) results in the highest drip loss, but also states, that medium levels (53 to 63 V AC) produce the best quality carcasses compared to low (0 to 23 V AC) and high (103 to 193 V AC) voltage. Comparing the stunning values from Regulation (EC) No. 1099/2009 (150 mA, 400 Hz) with the values used in the EU before the entry of this regulation (90 mA, 400 Hz), the study by Sirri et al. (2017) observed an improvement in water retention in meat but also an increase in the prevalence of bleeding into the pectoral muscle. Comparing the old and new electric current and frequency values, no differences were observed in relation to color, pH, cooking losses or meat tenderness. In a study by Siqueira et al. (2017), the effect of different stunning frequencies (300 Hz and 650 Hz) and wavelengths (direct current and alternating current) on the meat quality of broilers that were electrically stunned in a water bath at a voltage of 70 V and a current of 100 mA was investigated. Stunning broilers at a frequency of 300 Hz increased pectoralis major yield (PMY), but a frequency of 650 Hz increased the ability to retain water in the pectoral muscle. A study by Xu et al. (2011) indicated that stunning broilers with high frequency or a combination of high current and high frequency (65 V, 86 Ma A 1000 Hz) reduced cooking losses. Low current values using high frequency (400 or 1000 Hz) may worsen animal welfare and meat quality. However, high frequencies have the potential to improve meat quality if the current level is not too low (≥ 50 V, 67 Ma). In a study by Huang et al. (2017), the effect of different frequencies (500, 600, 700, 800 and 900 Hz)

at 15 V (12-14 mA) on broiler meat quality was also examined. Frequencies of 500 and 900 Hz significantly increased corticosterone and lactate values in blood plasma compared to stunning at 700 Hz. Significant damage to carcasses wings was noted at frequencies of 500 Hz, 800 and 900 Hz. The frequency of 700 Hz also showed a significantly lower damage to the pectoral muscle compared to the other groups. In the groups using frequencies of 500 and 900 Hz, higher values were observed in drip loss, but lower shear values were recorded.

Biochemical parameters of meat affected by electrical stunning

A potential indicator of good conditions at the slaughterhouse is absence of stress, but there is no standard definition of the environment or a specific biochemical system for measuring stress. However, an increase in plasma corticosterone is a recognized biochemical indicator of stress in poultry (Mercogliano et al. 2017). A study by Xu et al. (2011) noted, that low voltage or current is less effective in inducing unconsciousness and that electrical stunning can cause pain if the current is too low which is consistent with other previous studies. When combining the lowest current with high frequencies (35 V, 47 mA and 400 or 100 Hz), broilers suffered the most severe stress, which was reflected by the maximum plasma corticosterone (46.3 and 47.5 ng/ml). On the other hand, the least corticosterone (39.1 ng/ml) was detected with the combination of the highest current and the lowest stunning frequency (65V, 86 mA and 160 Hz). Therefore, the combination of low current with high frequency may reduce the effectiveness of stunning and cause more stress to broilers. Physical movement during an acute stress response during stunning releases glucose from muscles at a higher rate than during normal activity. Hence, increased glucose values in broiler meat are related to a higher stress during slaughter. When electrical stunning was compared to controlled atmosphere stunning, it was demonstrated that using electric stunning did not increase these values, as in the case of controlled atmosphere (Riggs et al. 2023). In this study, no differences in glucose values were noted when comparing housed broilers (272 mg/dL) with those just before stunning (283 mg/dL), and the values after stunning were even lower (259 mg/dL). The effect of frequency on glucose content was observed in a study by Siqueira et al. (2017) where they reported higher values of 226.56 mg/dL and 281.97 mg/dL for 300 Hz stunning (70 V, 100 mA) compared to 195.39 mg/dL and 208.18 mg/dL with a frequency of 650 Hz (70 V, 100 mA).

The impact of electrical stunning on PSE defect in broiler meat

An important aspect of broiler meat quality is color, which is the first characteristic consumers notice when purchasing meat. An easy and quick tool to distinguish PSE meat from normal meat is the lightness value as well as the pH value of the meat. Generally, chicken meat is categorized as PSE if the brightness is higher than 53 and the pH_{24} post-mortem is less than 5.7 (Dong et al. 2020). In a study by Siqueira et al. (2017), it was noted that among the observed samples, 23.53% of breast fillets had PSE meat characteristics. The combination of 300 Hz and direct current showed a 19% occurrence of PSE, while the same frequency combined with alternating current showed a 29% occurrence in breast fillets. Combinations of 650 Hz with direct current and alternating current demonstrated the occurrence of PSE in 24 and 23% of pectoral muscles. Huang et al. (2017) observed the effect of different frequencies (500, 600, 700, 800 and 900 Hz) at 15 V (12-14 mA), where a significant decrease in pH_2 at frequencies of 500 and 900 Hz (5.82 and 5.79) was noted. However, pH_{24} and lightness values after 2 and 24 hours were not affected. In a study by Sirri et al. (2017), stunning parameters before and after entry of regulation (EC) No. 1099/2009 were compared (90 mA, 400 Hz; 150 mA, 400 Hz), but they did not record

any differences in relation to pH_{ult} and no statistically significant differences were also noted in relation to meat color (lightness, shade of red and yellow). Significant differences in color and pH were noted by Kissel et al. (2015) in a study comparing a group of broilers electrocuted in a water mist with a group without stunning. The group that was stunned prior to killing showed statistically significantly higher mean pH values (5.87) compared to the non-stunned group (5.82). Significant differences were also noted in lightness and red spots in the meat with lower values in the stunning group. In connection with the PSE defect, the group without stunning showed up to 54.14% of broilers with this defect, which represented significantly higher values than the PSE prevalence in the group after stunning (25.0%).

Conclusions

The effects of electric stunning on the final meat quality, as well as on the quality and duration of stunning, depend on the parameters used, such as voltage, electric current and frequency. It is important to choose a suitable electric intensity to ensure that animals are stunned for a sufficient duration, thus preventing defects from insufficient stunning and stress from slaughter. At the same time, the chosen intensity should not negatively impact the final meat quality. In general, the use of electric stunning before slaughter has a positive effect on the occurrence of PSE defects in chicken meat as well as on the color of the meat. The quality and duration of unconsciousness in animals increases with the use of higher voltages, but lower values of electric voltage are associated with better meat quality and less damage to the carcasses. Different values of the technical parameters of the electric slaughter of broilers and their combination have shown effects on many quality indicators in the meat, and the appropriateness of their use depends on the desired effect of stunning. Therefore, meat producers should focus on the best possible quality of meat with the least possible damage to the carcasses when slaughtering broilers, but at the same time they should pay attention to sufficient stunning and welfare during stunning and slaughter.

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