Research Note

Effect of EU electrical stunning conditions on breast meat quality of broiler chickens

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ABSTRACT Electrical stunning is still the main stunning method used worldwide in commercial poultry plants. The stunning procedures in water bath stunners affect both bird welfare and meat quality attributes. The European Union (EU) Council Regulation 1099/2009 on the protection of the animal at the time of killing established the minimum current flow through an individual bird at a specified frequency to assure an effective stun that must last until the bird's death. The aim of this study was to compare the effect of the application of different stunning current flows on the prevalence of hemorrhages (classified as 1 = no lesion, 2 = moderate, and 3 = severe lesion) and some quality traits (pHu, color, drip and cooking losses, and shear force) of chicken breast meat. A total of 12 flocks of broiler chickens, each equally divided into light, medium, and heavy sizes, was submitted either to the stunning condition usually adopted before the entry into force of the current EU regulation (90 mA/bird, 400 Hz) (OLD) or to that enforced by it (150 mA/bird, 400 Hz) (NEW). Overall, the prevalence of severe hemorrhages dramatically increased in the NEW group in comparison with the OLD one (55 vs. 27%; $P < 0.001$) and particularly in heavy-sized birds (72 vs. 25%; $P < 0.001$). In general, meat quality attributes were not affected by the stunning conditions with the exception of drip loss that resulted lower in NEW than OLD birds (1.01 vs. 1.27; $P < 0.001$). In conclusion, the adoption of a higher current flow, as suggested by the EU regulation to protect animals at the time of killing, increases the prevalence of breast hemorrhages while maintaining meat quality traits with a possible beneficial effect on water holding capacity of fresh meat.

Key words: electrical stunning, current flow, meat quality, breast hemorrhages, broiler chicken

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INTRODUCTION

Animal welfare during slaughter was one of the major criteria that led to the development of legislative documents for stunning across the world. In the European Union (**EU**), stunning procedures have been regulated since 1974 (European Communities, 1974) and were subsequently implemented by the Directive 93/119/EC (European Union, 1993) that laid down common minimum standards for the protection of animals during slaughtering. More recently, the European Union (2009) has adopted the EU Council Regulation 1099/2009 on the protection of animals at the time of killing, which established specific requirements for different stunning methods in order to minimize any avoidable suffering, pain, and distress to the animal during slaughtering and related operations.

Electrical stunning is still the main method used in commercial poultry plants, both in the United States and Europe (Berg and Raj, 2015). Stunning must induce a state of unconsciousness and insensibility of sufficient duration to ensure that the animal does not recover while bleeding to death. The unconsciousness of broilers after electrical stunning is thought to be related to neural disruption of various nuclei and structures of the brain, which are essential for maintaining the waking state (Butler and Cotteril, 2006). This loss of consciousness and sensibility should be induced as soon as possible (Lambooij et al., 2010), and, during stunning, death may occur due to cardiac arrest and lack of oxygen to the brain (Turcsan et al., 2003).

It is widely known that stunning procedures in a water bath affect bird welfare as well as meat and carcass quality attributes (Joseph et al., 2013; Berg and Raj, 2015). Therefore, the selection of the stunning current parameters requires that welfare aspects of broilers during slaughter should be balanced against the commercial needs of the processing plant to preserve high carcass and meat quality standards (Barker, 2006). The current flow to achieve 90% of stunning efficiency varies

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according to the wave form applied and a minimum necessary stunning current of 70, 90, and 130 mA could be established, respectively, for sine wave AC, rectangular AC, and pulsed DC, even though a rapid and efficient bleeding is necessary to avoid the recovery of the birds before death when these parameters are applied (Prinz et al., 2012). Gregory et al. (1991) observed that the use of high amperage (110 vs 60 mA) leads to a 5-fold increase in ventricular fibrillation, which inhibits the recovery of chickens, leading them to death. On the other hand, the use of current flow lower than 100 mA (rectangular AC) did not induce an acceptable stunning effect on broiler chickens even if delivered at low frequencies and followed by a rapid and efficient bleeding (Prinz et al., 2010).

High-voltage stunning procedures have been linked to broken bones and breast meat hemorrhages (Gregory and Wilkins, 1989), while Bilgili (1992) observed no clear relationships between stunning amperage and whole carcass quality attributes. Low-voltage electrical stunning can decrease the prevalence of carcass quality damages and hemorrhages (Gregory, 1993; Heath et al., 1994) and influence bleed-out (Ali et al., 2007), whereas low current flows can affect meat color (Ahn et al., 2003) and AK-shear value up to 10 h postmortem (Papinaho and Fletcher, 1996). Finally, Wilkins et al. (1998) found that high stunning frequencies have a positive effect on carcass quality and decrease breast muscle hemorrhages in broilers.

The EU Council Regulation 1099/2009 established the minimum current flow through an individual bird at a specified frequency to assure an effective stun that must last until the bird's death. However, the current flows imposed by the EU regulation are quite higher in respect to those that were commonly used in commercial poultry slaughterhouses in the EU until the entry into force of the current legislation. Therefore a trial was carried out to estimate the effect of the application of such different stunning conditions on the prevalence and severity of hemorrhages and some quality traits of chicken breast meat.

MATERIALS AND METHODS

This trial was carried out in a commercial slaughter plant for broiler chickens adopting electrical stunning procedures. For stunning, birds were immersed in an electrified water bath (using square wave alternating current, 400 Hz) up to the base of their wings. A total of 12 flocks of broiler chickens, equally divided into light (1.740 kg live weight, females), medium (2.600 kg live weight, females), and heavy (3.400 kg live weight, males) sizes was submitted either to the stunning condition usually adopted before the entry into force of the current EU regulation (90 mA/bird, 400 Hz) (**OLD**) or to that enforced by it (150 mA/bird, 400 Hz) (**NEW**). After the stunning procedure, birds were immediately killed by severing the jugular vein and carotid artery with an automatic device and allowed bleeding. Subsequently, broilers were scalded (51 to 52°C for 215 s for light- and medium-sized birds, 51 to 52°C for 280 s for heavy-sized birds), plucked, eviscerated, and chilled.

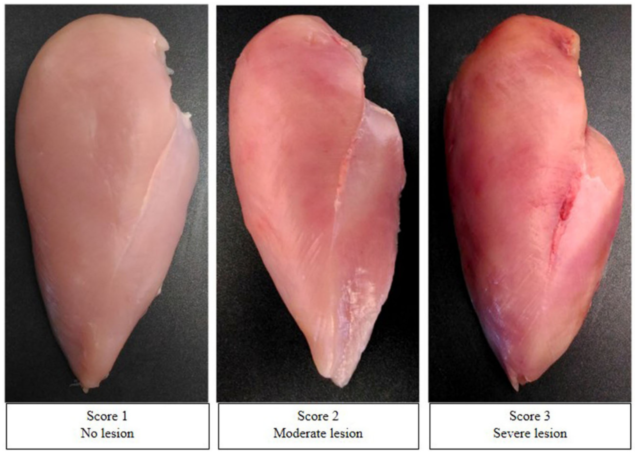

Figure 1. Criteria used for the evaluation of hemorrhages in breast fillets of chickens submitted to stunning conditions applied before (OLD) or after (NEW) the entry into force of the EU regulation.

After chilling, 100 carcasses per group for a total of 1,200 were cut and deboned and breasts evaluated for prevalence and severity of hemorrhages. The hemorrhages were evaluated on the external surface of the *Pectoralis major* and quantified using a visual grading system based on 3 scoring categories (1 = no lesion, 2 = moderate, and 3 = severe lesion; Fig. 1). Moreover, 15 right breast fillets per group (in total 180 fillets) were randomly collected and used for the determination of color profile, ultimate pH, drip and cook loss, and Allo-Kramer (**AK**) shear values after cooking. The CIE (1978) system color profile of lightness (L^*), redness (a^*), and yellowness (b^*) was performed by a reflectance colorimeter (Minolta Chroma Meter CR-300, Minolta Italia S.p.A., Milan, Italy) using illuminant source C. Breast meat color was evaluated averaging 3 measurements taken on the medial surface of the fillet (bone side) in an area free of obvious color defects. Breast meat pH was measured 48 h postmortem using a modification of the iodoacetate method initially described by Jeacocke (1977). Approximately 2.5 g of meat were removed from the cranial end of the *Pectoralis major*, minced by hand, and homogenized in 25 mL of a 5 m*M* iodoacetate solution with 150 m*M* of potassium chloride for 30 s, and the pH of the homogenate was determined using a pH meter (pH meter Crison Basic 20+, Crison Strumenti, SpA, Carpi, Italy) calibrated at pH 4.0 and 7.0. Drip loss was analyzed on one intact fillet from each of 15 birds/group, kept suspended in a sealed glass box for 48 h at 2 to 4°C, and calculated as percentage of weight loss during storage. Cook loss was measured on the same fillet by cooking intact muscles (*Pectoralis major*) on aluminum trays in a convection oven at 180°C until 80°C at core sample was reached. The samples were allowed to equilibrate to room temperature, then reweighed, and cook loss was determined as percentage of weight loss. Shear values were determined using an Instron universal testing machine (Instron, ITW 3600, West Lake Ave Glenview, IL) equipped with an AK shear cell. Cooked meat samples (approximately 2 × 4 × 1 cm) were cut parallel to the muscle fiber direction from each fillet (*Pectoralis major*: cranial position) and sheared with the blades at a right angle to the fibers using a 250-kg load cell and crosshead speed of 500 mm/min (Papinaho and Fletcher, 1996). Allo-Kramer shear values were reported as kilograms of shear per gram of sample.

Data were evaluated by using one-way ANOVA for the analysis of meat quality attributes while the prevalence of hemorrhages was analyzed using the chi-square test (SAS Institute, 1988).

RESULTS AND DISCUSSION

Figure 2 shows the prevalence of overall breast hemorrhages of broiler chickens submitted to OLD or NEW stunning conditions, as well as the prevalence of breast hemorrhages in the 3 different commercial weight categories (light, medium, and heavy sizes). Only 11% NEW birds had no hemorrhages compared to OLD ones (27%) ($P < 0.001$). The prevalence of moderate hemorrhages resulted lower in NEW than OLD birds (34 vs. 46%, respectively), while severe hemorrhages were considerably higher in NEW ones (55 vs. 27%; $P < 0.001$).

As for light-sized birds, 25% of NEW chickens had no hemorrhages compared to OLD ones (37%) ($P < 0.01$). The prevalence of moderate hemorrhages was similar (29 vs. 41%, respectively, for NEW and OLD; $P < 0.01$). The prevalence of severe hemorrhages resulted higher in NEW birds compared to OLD ones (46 vs. 22%, respectively; $P < 0.01$). The distribution of the occurrence of hemorrhages for medium-sized birds was similar to that described for light birds with the exception of moderate hemorrhages, which did not differ in the 2 groups ($P < 0.01$). About 99% of NEW heavy-sized birds showed breast hemorrhages, of which 27% were moderate (category 2) and 72% were scored as severe (category 3) ($P < 0.001$). The OLD stunning procedure had a lower impact on the prevalence of breast hemorrhages, since 55% were classified as moderate (category 2) and 25% as severe (category 3) ($P < 0.001$). In a recent study, Huang et al. (2016) observed that increasing the stunning voltage from 15 to 45 V (pulsed DC at 750 Hz for 10 s) led to an increase of damage in both *P. major* and *P. minor*. Lambooij et al. (2010) compared the conventional water bath method to head-only stunning using an electrical current flow of 240 mA (~100 V, sinusoidal AC wave) delivered at a frequency of 50 Hz and found that the percentage of fillets with blood splashes was 20% after head-only stunning compared to 84% after conventional stunning, of which 12% displayed severe blood splashes. Although the authors applied a higher current flow and a lower frequency than those we used, the prevalence of overall hemorrhages (>80% in birds whole-body electrical stunned) was similar to that found in this trial.

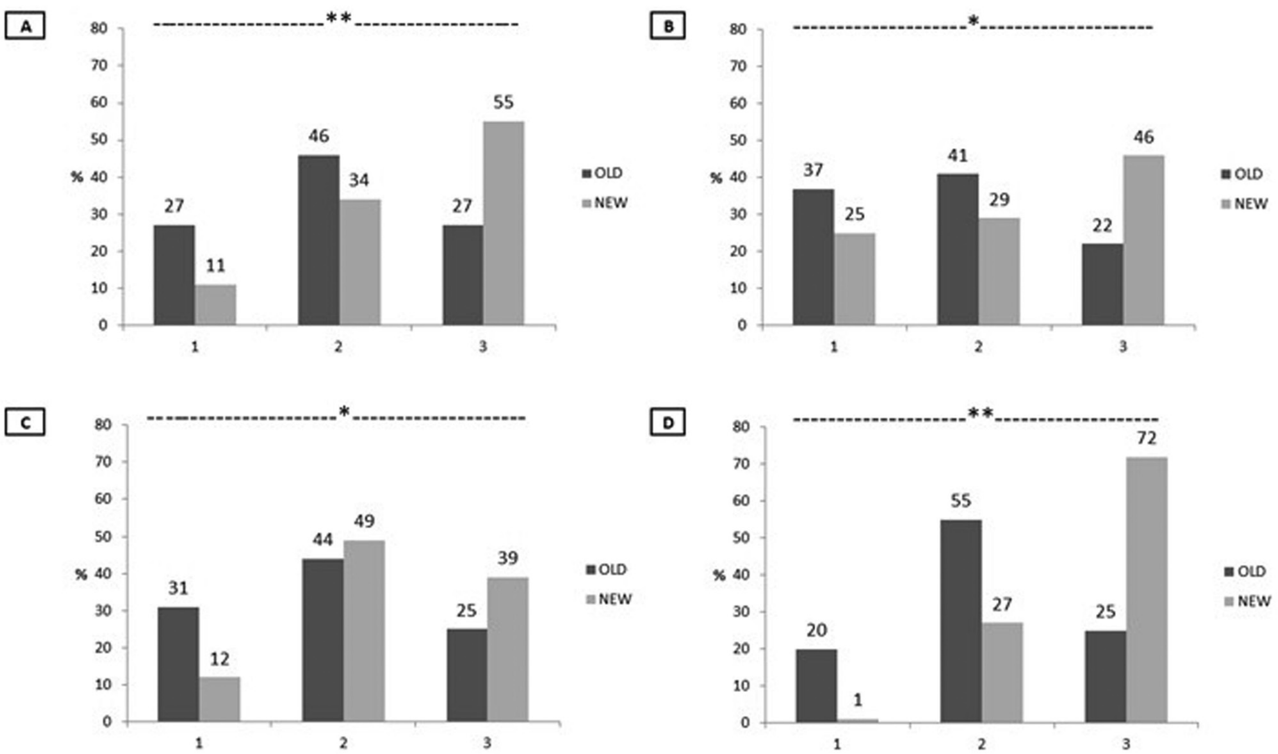

Figure 2. Prevalence of hemorrhages in breast meat of chickens belonging to different commercial body weight categories (A: overall; B: light-sized; C: medium-sized; D: heavy-sized) classified as without lesion (score 1), moderate lesion (score 2), and severe lesion (score 3) and submitted to stunning conditions applied before (OLD)[1] or after (NEW)[2] the entry into force of the EU regulation. [1]OLD: 90 mA/bird, 400 Hz. [2]NEW: 150 mA/bird, 400 Hz. *: $P < 0.01$; **: $P < 0.001$.

Table 1. Quality traits of breast meat of chickens submitted to stunning conditions applied before (OLD) or after (NEW) the entry into force of the EU regulation.

	Stunning conditions			
	OLD[1]	NEW[2]	ESM	*P*-value
Ultimate pH	5.94	5.93	0.01	0.412
Lightness (L*)	51.7	52.4	0.29	0.208
Redness (a*)	1.80	2.02	0.07	0.109
Yellowness (b*)	1.55	2.00	0.17	0.186
Drip loss (%)	1.27	1.01	0.03	<0.001
Cooking loss (%)	20.1	21.0	0.33	0.085
AK-shear value (kg/g)	2.31	2.34	0.04	0.655

[1]OLD: 90 mA/bird, 400 Hz.
[2]NEW: 150 mA/bird, 400 Hz.

Wilkins et al. (1998) observed a marked reduction of the prevalence of breast muscle hemorrhages using high frequency DC (500 and 1,500 Hz pulsed square wave DC) instead of low frequency AC (50 Hz sinewave AC, 50 Hz thyristor modified sinewave clipped AC, 100 Hz fully rectified sinewave). Similar results also were reported in turkeys in which the application of a high frequency waveform (1,400 Hz pulsed DC square wave) reduced hemorrhagic downgrading conditions of breast muscles with respect to using low stunning frequency (50 Hz sinewave AC) (Wilkins and Wotton, 2002). However, since in these studies different waveforms were used, any comparison with our results must be done carefully.

In Table 1 the effects of OLD or NEW stunning conditions on meat quality traits are given. In general, the meat quality attributes were not affected by the stunning conditions adopted in this experiment with the exception of drip loss. Birds stunned with NEW parameters had a lower drip loss than OLD ones (1.01 vs. 1.27%; respectively; $P < 0.001$). This result was observed in all birds of the 3 commercial categories of weight (data not shown). Similarly, Huang et al. (2014) observed higher drip loss in breast fillets of broilers stunned with 48 to 52 mA/bird (50 V AC at 50 Hz for 10 s) with respect to those stunned with 106 to 110 mA/bird (100 V at 50 Hz for 5 s). Recently, Huang et al. (2016), applying different stunning voltages (5, 15, 25, 35, and 45 V pulsed DC at 750 Hz for 10 s), observed that the use of the lowest one determined the highest drip loss of breast meat. The authors attributed these results to the lower initial pH value observed in the group stunned with the lower current flow. This current flow was not intense enough to induce deep unconsciousness of the broilers that exhibited strong wing flapping and struggling in the shackle line, determining a rapid postmortem glycolysis and lactate accumulation. A rapid pH decline, especially when the carcass is still warm, led to the denaturation of several proteins, including those involved in water holding capacity (Huff-Lonergan and Lonergan, 2005; Huang et al., 2014). Considering that delivering 150 mA at 400 Hz should induce deep unconsciousness in 94 to 96% of broilers (EFSA, 2012) and also that current flows lower than 100 mA failed to induce an acceptable stunning effect (Prinz et al., 2010), it is possible that the higher drip loss observed in OLD fillets compared to NEW ones might be ascribed to the mechanism described by Huang et al. (2014). However, since wing flapping and breast meat pH decline were not recorded in this trial, further studies are necessary to better understand the causes lying behind the improvement of water holding capacity of fresh meat during storage when high current flows are applied.

Ultimate pH of breast meat was not significantly affected by the electrical stunning parameters used in our trial. Similar results were reported in broilers (Papinaho and Fletcher, 1996; Lambooij et al., 2010; Huang et al., 2014, 2016) and turkeys (Sante et al., 2000) submitted to different electrical stunning conditions.

No significant difference in meat color parameters (L*, a*, b*) was observed between OLD and NEW breast fillets. Similarly, Huang et al. (2014, 2016) did not find any difference in breast meat color in relation to different stunning conditions. Also Craig and Fletcher (1997) reported no difference in breast meat color in birds stunned by high amperage or low voltage.

Cook loss resulted similarly between the OLD and NEW groups, confirming the results reported by Papinaho and Fletcher (1996) and Huang et al. (2014, 2016).

Meat tenderness was not affected by the stunning conditions tested in this trial since shear value resulted similarly between OLD and NEW groups. Huang et al. (2014) observed a significant increase in shear force using high current flow (106 to 110 mA/bird vs. 48 to 52 mA/bird, both at 50 Hz for 5 and 10 s, respectively) while recently reporting a lower shear value of breast meat by stunning the birds using 5 or 45 V instead of 15, 25, or 35 V (pulsed DC at 750 Hz for 10 s) (Huang et al., 2016).

The application of different current flows resulted in different and contrasting effects in animal welfare and meat quality. On the other hand, using a higher current flow as suggested by the EU regulation to protect animals at the time of killing increases the prevalence of breast hemorrhages while maintaining meat quality traits with a possible beneficial effect on water holding capacity of fresh meat.

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