Effects of Electrical Stunning Frequency and Voltage Combinations on the Presence of Engorged Blood Vessels in Goose Liver

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ABSTRACT The purpose of this study was to investigate the influence of nine electrical stunning methods using various frequency and voltage combinations on the occurrence of engorged blood vessels in goose liver. Two hundred seventy Gourmaud geese (liver-type line SI 14) were slaughtered at 12 wk of age, in groups of 90 at three different times. Thirty birds each were subjected to one of the nine stunning methods. Neck cutting was performed immediately after stunning. The duration of exsanguination was 11 min. After completion of bleeding, the birds were scalded, defeathered manually, and kept refrigerated. At 1 d postmortem, the carcasses were eviscerated and cut up. From the slaughterhouse, the livers chilled in ice were transported to the cannery where they were weighed and graded at 2 d postmortem and were further processed. All of the veins and capillaries full of blood were removed from livers, because their presence was a hazard to product quality by causing discoloration of the canned liver, and the percentage of liver weight loss was then determined. The loss in liver weight due to removal of engorged blood vessels was reduced ($P < 0.05$) at 350 Hz, 70 to 90 V, and 80 to 85 mA when compared to the results obtained with any other stunning method tested. It was concluded that the use of high-frequency currents for electrical stunning of liver geese might have considerable commercial advantages.

(*Key words*: electrical stunning, frequency, voltage, blood vessel, goose liver)

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INTRODUCTION

Hungary is the world's top producer of raw goose liver. Therefore, this product is regarded as a Hungarian specialty in many countries. Large quantities of this commodity are exported to France. In fact, Hungary's goose liver exports make up approximately two-thirds of goose liver imports by France. The further-processed product, known as foie gras, is a great delicacy.

In recent years, there has been considerable public concern for the welfare of food animals, including poultry species, during stunning and slaughter. The European Union (1993) adopted detailed welfare-at-slaughter rules, which are set down in Council Directive 93/119/EC on the protection of animals at the time of slaughter or killing. Presently, the technologies to humanely stun and slaughter poultry are widely employed. The methods legally usable for stunning include captive bolt pistol, concussion, electronarcosis, and exposure to carbon dioxide.

From an animal welfare perspective, stunning should produce a rapid onset of stress-free insensibility of sufficient duration to allow the bird to remain unconscious until dead, either as a result of the stun itself or due to subsequent killing operations such as neck cutting during slaughter (Fletcher, 1999; Savenije et al., 2002). Electrical water-bath stunning is the most common method of immobilizing birds for easier killing in commercial poultry processing plants (Bilgili, 1992; Raj, 1998; Savenije et al., 2002). Electricity is convenient, economical, and requires little room. Much diversity exists in electrical equipment, concepts, and approaches to water-bath stunning. Electrical stimuli vary with respect to magnitude (current and voltage), duration (length of the water bath and line speed), oscillation frequency, waveform, current direction, and energy (Kranen et al., 2000). By passing sufficient electric current through the brain, a general epileptiform insult will occur, which is characterized by rapid and excessive depolarization of the membrane potential (Fricker and Müller, 1981). Upon electrical stunning the animal may die due to a heart attack and loss of oxygen to the brain. Insufficient currents may physically immobilize the bird but may not prevent perception of pain, stress, or discomfort by the animal (Bilgili, 1999). Stunning with high electrical currents is a humane method, when compared to low amperage or no stun, because there is less likelihood of a bird regaining consciousness before death (Gregory and Wotton, 1986). However, the high amperage applied in Europe causes more carcass and meat

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damage than the lower amperage customarily used in the United States (Craig and Fletcher, 1995; Hillebrand et al., 1996; Kang and Sams, 1999). Appearance defects result in a decline in sales and, thus, economic losses to poultry processors (Fricker and Müller, 1981).

The conflict between welfare and meat quality with the conventional low-frequency (50 Hz) water-bath stunning systems has provided the incentive for further developments in the area of stunners operating at high frequencies (>100 Hz). The use of high-frequency currents for electrical stunning of poultry may result in a marked improvement in carcass quality (Wilkins et al., 1998, 1999; McNeal et al., 2003).

The literature on stunning in swine, cattle, and broilers is abundant, but there is little information about preslaughter electrical stunning in geese (Schütt-Abraham et al., 1992; Turcsán et al., 2001). The objective of this research was to investigate the effects of electrical stunning methods with various voltage and frequency combinations on the occurrence of engorged blood vessels in goose liver.

MATERIALS AND METHODS

Experimental Birds

In previous force-feeding trials, the Gourmaud goose hybrid has been found to have optimum liver production characteristics (Szigeti et al., 1999). Therefore, this experiment was carried out with Gourmaud geese (liver-type line SI 14). Ninety birds, reared under common conditions and, as a result, varying in body size by no more than 10% (i.e., 7.2 to 7.9 kg of live weight), were slaughtered at 12 wk of age. Ten each were subjected to one of the nine stunning methods tested. The geese were removed from feed and held in coops 8 h prior to slaughter. The entire experimental program was repeated three times.

Electrical Stunning

The geese were hung by their feet in steel shackles and were electrically stunned in a water bath for 8 s. The control group was stunned with a conventional low-frequency (50 Hz) water-bath stunner[2] customarily used in the poultry processing plant of Merian Orosháza Inc. (Orosháza, Hungary). Another group of geese was subjected to stunning in the same stunner equipped with a special frequency modulator.[3] The maximum stunning frequency achievable with the latter system was 200 Hz. In addition, seven more groups of Gourmaud geese were stunned in a recently developed variable frequency stunner[4] that used various frequency and voltage combinations as shown in Table 1.

[2]Model VKA-67, Monori Gépgyártó Vállalat, Monor, Hungary.
[3]Model BA 4, Lindholst & Co. A/S—Linco, Trige, Denmark.
[4]Model HD II-3.5 F, Stork PMT B.V., Boxmeer, The Netherlands.
[5]Model HF-2000-EC, A&D Instruments Ltd., Abingdon, UK.

TABLE 1. Technological parameters of electrical stunning in geese

Stunner	Frequency (Hz)	Voltage (V)	Current (mA)
Control[1]	50	50	75
Linco[2]	200	100	75
Stork 1[3]	50	50	75
Stork 2[3]	200	90	80
Stork 3[3]	200	110	90
Stork 4[3]	350	50	65
Stork 5[3]	350	70	80
Stork 6[3]	350	90	85
Stork 7[3]	350	110	90

[1]Model VKA-67 (Monori Gépgyártó Vállalat, Monor, Hungary).
[2]Model VKA-67 equipped with a BA 4 frequency modulator (Lindholst & Co. A/S, Linco, Trige, Denmark).
[3]Model HD II-3.5 F (Stork PMT B.V., Boxmeer, The Netherlands).

Processing

Neck cutting was performed immediately after stunning. The duration of exsanguination was 11 min. After completion of bleeding, the birds were scalded (62°C, 5 min), defeathered (for 2.5 min) manually, and kept refrigerated (0 to 2°C, 1 d). At 1 d postmortem, the carcasses were eviscerated and cut up. From the slaughterhouse, the livers chilled in ice were transported to the cannery where they were weighed and graded at 2 d postmortem and were then further processed.

Determination of Liver Weight Loss

Because weight is one of the major characteristics influencing the general appearance and, thus, the value of raw goose liver (Szigeti et al., 1999), livers were weighed using a precision balance.[5] It should be noted that the livers evaluated in this study were similar in size, ranging from 580 to 620 g in weight. All of the veins and capillaries full of blood were removed in the course of processing because their presence is a hazard to product quality by causing discoloration of the canned liver. The degree of loss of liver weight caused by trimming engorged blood vessels, however, is of concern to processors. Therefore, the livers were weighed twice, i.e., before and after removal of blood vessels, and the difference was expressed in terms of a percentage.

Statistical Analysis

The data obtained were subjected to ANOVA using the general linear model procedure of STATISTICA data analysis software system, version 6 (StatSoft, 2001). Significant differences among the means were determined by using Duncan's multiple range test at $P < 0.05$ (StatSoft, 2001).

RESULTS

The effect of various electrical stunning methods on liver weight loss due to removal of veins and capillaries

TABLE 2. Influence of various stunning methods on goose liver weight loss caused by removal of engorged blood vessels

Stunning method[1]	Liver weight loss (%)[2]
Control (50 Hz-50 V)	11.29 ± 1.83[bc]
Linco (200 Hz-100 V)	12.63 ± 1.79[a]
Stork 1 (50 Hz-50 V)	11.71 ± 1.43[b]
Stork 2 (200 Hz-90 V)	11.77 ± 1.68[b]
Stork 3 (200 Hz-110 V)	12.16 ± 1.70[ab]
Stork 4 (350 Hz-50 V)	10.55 ± 1.41[c]
Stork 5 (350 Hz-70 V)	8.67 ± 1.34[d]
Stork 6 (350 Hz-90 V)	7.68 ± 1.71[e]
Stork 7 (350 Hz-110 V)	11.75 ± 1.45[b]

[a–e]Values without a common superscript letter differ significantly ($P < 0.05$).

[1]For detailed technological parameters see Table 1.

[2]Values are means ± SD based on 30 observations (10 samples, 3 replicates).

is shown in Table 2. The loss in liver weight of 11.29% caused by trimming engorged blood vessels after stunning with a low-frequency (50 Hz) control stunner was similar to our previous findings (Turcsán et al., 2001). However, this value was lower ($P < 0.05$) than that obtained with the Linco system, i.e., control stunner equipped with a special frequency modulator, at 200 Hz. Unlike Linco, the variable frequency stunner of Stork did not produce poorer results in terms of liver weight loss at any frequency level tested than the control system. Frequency values up to 200 Hz were found to have no effect ($P > 0.05$) on this parameter. At 350 Hz, however, the percentage of liver weight loss decreased greatly with increasing voltage, reaching optimum results between 70 and 90 V and then it increased again at 110 V. Interestingly, the highest voltage of 110 V gave losses equivalent to the control group.

DISCUSSION

The frequency and voltage of the applied electrical current are determining factors in the effectiveness of electronarcosis (María et al., 2001). Electrical stunning causes a sharp increase in blood pressure, especially in the veins. As a result, blood vessels may rupture, thereby causing bleeding (Kranen et al., 2000). In geese, this represents a serious hazard to liver and meat quality. Stunning with higher current frequencies is one of the alternatives to conventional low-frequency (50 Hz) water-bath stunning (Hillebrand et al., 1996; McNeal et al., 2003). It has been suggested that high-frequency (500 Hz) stunning currents affect the central nervous system to a greater degree than the muscular system compared to low-frequency (50 to 60 Hz) currents, which have more influence on the muscular system (Craig and Fletcher, 1997). Thus, it might be possible to kill birds following a high-frequency stun without a massive muscular contraction.

The most plausible explanation of our observations is that the conventional low-frequency waveforms tended to result in muscle and blood vessel spasms to a larger extent than did the higher current frequencies (Craig and Fletcher, 1997; Turcsán, 2001). Therefore, it is suspected that the differences observed in liver weight loss resulting from trimming engorged blood vessels might have been due to variation in the degree of vasoconstriction caused by the stunning current. Another possibility is that low-frequency currents might have induced ventricular fibrillation in geese, and this had serious consequences for liver quality because a poorly functioning heart with signs of ventricular fibrillation was incapable of completely eliminating blood from the blood vessels of liver. In contrast, high stunning current frequencies might have induced a lower incidence of ventricular fibrillation (Gregory et al., 1991; Wilkins et al., 1998) and, thus, had a beneficial effect on liver quality by contributing to elimination of blood from the liver veins and capillaries. This would have reduced the number of blood vessels to be removed that might cause discoloration of the canned liver. Our findings are consistent with those of Kuenzel and Ingling (1977) who demonstrated that increasing the frequency of stunning currents from 30 to 240 Hz improved bleedout efficiency. High stunning current frequencies up to 1,500 Hz have also been reported to reduce the incidence and severity of thigh and breast muscle hemorrhages and result in fewer broken bones in various poultry species (Hillebrand et al., 1996; Wilkins et al., 1998, 1999; Raj et al., 2001). However, Gregory et al. (1991) did not confirm that increasing frequency, between the limits of 50 and 350 Hz, was associated with a corresponding reduction in the incidence of hemorrhages in the carcasses. When evaluating the effects of varying frequency (60, 200, 350, 500, and 1,000 Hz at 40 V) on breast meat quality of chickens, Contreras and Beraquet (2001) found minimum carcass defects at 1,000 Hz. In turkeys, the use of a high-frequency (1,400 Hz) waveform resulted in faster bleedout and improvements in carcass quality associated with a substantial reduction in hemorrhagic downgrading conditions (Wilkins and Wotton, 2002). Our findings are consistent with these results in that they suggest that use of high-frequency stunning currents for electrical stunning of geese could have considerable commercial advantages.

In conclusion, the loss of liver weight caused by trimming engorged blood vessels can be reduced considerably if an appropriate stunning method is applied. At 350 Hz, 70 to 90 V, and 80 to 85 mA, the variable frequency stunner of Stork was found to be most suitable for the preslaughter stunning of geese used for liver production. With this system, the major electrical parameters (frequency, voltage, current levels) can be adjusted easily and accurately in order to stun various poultry species under commercial conditions, and this may be of great importance to slaughterhouses that have only one processing line.

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