

The Effects of Electrical and Controlled Atmosphere Stunning Methods on Meat and Liver Quality of Geese

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ABSTRACT The objective of this research was to investigate the effects of electrical and gas stunning on the meat and liver quality characteristics of liver geese. Sixty birds were slaughtered at 12 wk of age, in groups of 20 at three different times. Thirty birds each were subjected to one of the two stunning methods. Deboned breast fillets and thigh muscles were evaluated for hemorrhaging, amount of blood in the veins, and color by using a visual grading system. Livers were removed from carcasses during evisceration and were subsequently graded. Besides external color and hemorrhaging, the degree of liver weight loss due to removal of blood vessels was also determined. The use of controlled atmosphere stunning

significantly reduced the incidence of muscle hemorrhages when compared to electrical stunning. However, no significant difference was found for color or amount of blood remaining in the veins of muscles between geese receiving electrical or controlled atmosphere stunning. The hemorrhaging and color scores of livers from gas-stunned birds did not differ from those of electrically stunned birds. As for the liver weight loss caused by removal of veins and capillaries, stunning treatment had no significant effect on this parameter. These results suggest that controlled atmosphere stunning produced slightly better quality goose meat but did not improve liver quality when compared to the electrical stunning method used.

(*Key words:* stunning, goose, liver quality, meat quality, hemorrhage)

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INTRODUCTION

The majority of poultry are stunned prior to slaughter, and neck cutting is performed after a state of unconsciousness and insensitivity to pain is induced (Hillebrand et al., 1996; Wilkins et al., 1998; Gerritzen et al., 2000). Electrical water bath stunning is the most common way of immobilizing birds in commercial poultry processing plants (Bilgili, 1992; Raj, 1998; Tserveni-Gousi et al., 1999). Electrical stunning causes depolarization of neurons in the brain, which results in brain function disturbances in the form of a general epileptiform insult (Fricker and Müller, 1981). 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 the bird's regaining consciousness before it dies (Gregory and Wotton, 1986). However, the high amperage applied in Europe causes more carcass and meat damage than the lower amperage customarily used in the United

States (Veerkamp et al., 1987; Gregory and Wilkins, 1989; Gregory, 1992; 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; Alisch and Obdam, 1992).

Evidently, there is some conflict between animal welfare and meat quality. Therefore, it is essential that alternative stunning methods be explored. Electrical stunning with high current frequencies is one of the alternatives to conventional low frequency (50 Hz) water bath stunning (Hillebrand et al., 1996). The use of high frequency (≥ 480 Hz) stunning currents results in an increased rate of post-mortem pH decline and improved meat quality, compared to the lower frequency (≤ 350 Hz) waveforms (Gregory et al., 1991; Wilkins et al., 1998, 1999; Sante et al., 2000). These results can be accounted for by the fact that higher current frequencies cause a lower degree of direct stimulation of tonic muscle contraction and, thus, result in fewer carcass and meat defects (Hillebrand et al., 1996).

Another alternative to the conventional whole-body electrical stunning is head-only stunning—during which the current passes through only the head of the animal—because it causes a lower incidence of broken bones and less severe hemorrhages than does whole-body stunning in thigh and breast muscles (Kranen et al., 1996). However, it should be noted that whole-body stunning in-

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duces immediate brain damage, whereas head-only stunning does not always produce an adequate stun (Savenije et al., 2000).

Mechanical (i.e., captive bolt, air pressure, concussion, etc.) stunning methods also represent an alternative to the various electrical stunning systems. Their use results in meat quality similar to that obtained with head-only stunning (Hillebrand et al., 1996; Göksoy et al., 1999; Lambooj et al., 1999).

Since the early 1990s, there has been considerable public concern for the welfare of animals during stunning and slaughter. The European Union (1993) adopted detailed welfare-at-slaughter rules in 1993. These rules 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. Various gaseous stun-kill systems have been developed with the results of human anesthesiology. Hoen and Lankhaar (1999) reported that gas stunning and killing of poultry could be realized by the depletion of oxygen (anoxia), by increasing the CO₂ concentration of the gas mixture (hypercapnic hypoxia), or a combination of these two methods (hypercapnic anoxia). However, an increased level of CO₂ in combination with a lack of O₂ may cause excitation or convulsions in the birds. To prevent such adverse reactions, the concentrations of CO₂ and O₂ in the stunning atmosphere should be carefully controlled. After becoming unconscious, the birds can be killed painlessly by using a gas mixture with a high concentration of CO₂ (Coenen et al., 2000).

Hoenderken et al. (1994), Raj (1998), and Gerritzen et al. (2000) pointed out that chickens, turkeys, and quail could be stunned and killed very humanely using various gas mixtures (e.g., 90% Ar in air, 60% Ar + 30% CO₂ in air, 40% CO₂ + 30% O₂ in air, or 40 to 60% CO₂ in air). Gas stunning eliminates the problem of broken bones, significantly reduces hemorrhaging in leg and breast muscles, and increases the rate of postmortem pH decline, thereby resulting in improved carcass quality compared to electrical stunning (Raj et al., 1990; Kang and Sams, 1999; Tserveni-Gousi et al., 1999). For a century, attempts have been made to use CO₂ as an anesthetic agent. However, this gas was not applied to stunning of poultry until the mid 1950s (Drewniak et al., 1955). Subsequent research revealed that CO₂ stunning had a beneficial effect on bleeding efficiency (Kotula et al., 1957) and resulted in better meat quality (Zeller et al., 1988). Kang and Sams (1999) reported that the lower incidence of damage to the carcasses stunned by CO₂ was due to the calmer nature of birds during a gaseous stun.

To date, the influence of gas stunning on geese used for liver production has not been examined. The purpose of this study was to investigate the effects of controlled atmosphere stunning and conventional electrical stunning on meat and liver quality attributes of liver geese.

TABLE 1. Technological parameters of controlled atmosphere stunning

Parameter controlled	Phase 1	Phase 2
Duration	1 min	2 min
Atmosphere	30% O ₂ 40% CO ₂ 30% N ₂	5% O ₂ 80% CO ₂ 15% N ₂
Temperature	20 C	20 C
Relative humidity	60–65%	60–65%

MATERIALS AND METHODS

Experimental Animals

In previous force-feeding trials, the Gourmaud goose hybrid has been found to have optimum meat and liver production characteristics (Szigeti et al., 1999). Therefore, this experiment was carried out with Gourmaud geese (liver-type line SI 14). Twenty birds, reared under common conditions, were slaughtered at 12 wk of age. Ten each were subjected to one of the two stunning methods. The geese were removed from feed and held in coops 8 h prior to slaughter. The entire experimental program was repeated three times.

Gas Stunning

As shown in Table 1, the controlled atmosphere stunning system² included two phases. During the initial phase, the geese were stunned with a sleep-inducing atmosphere consisting of a relatively low concentration of CO₂ and an increased level of O₂, with the rest of the atmosphere being N₂. The humidity level of the gaseous atmosphere also played an important role during this phase and was kept at the humidity level of the ambient air or higher. Failing to provide this condition would have resulted in dehumidification of the mucous membranes, thus causing stress to the birds that could have been avoided. During the final phase, the geese were subjected to an increased level of CO₂ and a reduced O₂ concentration. This atmosphere had a killing effect. The birds never regained consciousness. Their deaths were caused by suffocation.

Electrical Stunning

The geese were hung by their feet in steel shackles and were electrically “head-only” stunned in water bath³ using 50 Hz, 50 V, and 75 mA for 8 s.

TABLE 2. Meat quality rating scale

Parameter	Score		
	1	2	3
Hemorrhaging	None	Mild	Severe
Blood in veins	None	Tolerable amount	Objectionable amount
Color	Light	Normal	Dark

²Prototype, Stork PMT B.V., 5830 AC Boxmeer, The Netherlands.

³Model VKA-67, Monori Gépgyártó Vállalat, 2200 Monor, Hungary.

TABLE 3. Meat quality scores¹ from geese stunned with controlled atmosphere (CAS) or electricity (ES)

Parameter evaluated	Breast muscles		Thigh muscles	
	CAS	ES	CAS	ES
Hemorrhaging	1.03 ± 0.18 ^b	1.36 ± 0.50 ^a	1.06 ± 0.26 ^b	1.27 ± 0.47 ^a
Blood in veins	2.00 ± 0.77 ^a	2.09 ± 0.54 ^a	1.92 ± 0.67 ^a	1.83 ± 0.58 ^a
Color	1.63 ± 0.51 ^a	1.55 ± 0.42 ^a	1.18 ± 0.40 ^a	1.27 ± 0.47 ^a

^{a,b}Values within a row within variable, with no common superscript differ significantly ($P < 0.05$).

¹Values are means ± SD based on 150 observations (5 panelists, 10 samples, 3 replicates).

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 then kept refrigerated (0 to 2 C, 1 d). At 1 d postmortem, the carcasses were eviscerated and cut up, and meat quality traits were assessed. The preliminary grading of livers took place immediately after evisceration. From the slaughterhouse, the livers chilled in ice were transported to the cannery where they were weighed and graded at 2 d postmortem.

Examination of Meat Quality

Five experienced panelists evaluated deboned breast fillets and thigh muscles from each carcass for the parameters indicated in Table 2 using a three-point rating scale.

Examination of Liver Quality

Livers were evaluated by the same panelists for color and hemorrhages. External color and the incidence and severity of hemorrhages were determined by means of a three-point scale similar to that used for meat evaluation. Liver weight and the liver weight loss due to removal of blood vessels were also measured.⁴ Livers were weighed during the grading procedure because weight is one of the major characteristics influencing the general appearance of liver (Szigeti et al., 1999). 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. However, the degree of liver weight loss due to removal of blood vessels is of concern to processors. Therefore, the livers were weighed both before and after removal of blood vessels and the difference was expressed in terms of a percentage.

Statistical Analysis

The effect of stunning procedure on meat and liver quality attributes of geese was analyzed with the Stu-

dent's *t*-test, by means of the STATISTICA™ 4.5 software (StatSoft, 1994). In all cases, $P < 0.05$ was considered significant.

RESULTS

Effect of Stunning Method on Meat Quality

The controlled atmosphere stunning system caused little hemorrhaging in the muscles of geese (Table 3). The birds stunned with gaseous atmosphere had significantly fewer breast muscle hemorrhages than did those stunned electrically. However, no significant difference was found for blood remaining in the veins of breast muscles of geese receiving electrical or gas stunning. As for the color of breast fillets, neither treatment resulted in an excellent score, and the means were not significantly different.

In the thigh muscles, the use of controlled atmosphere stunning significantly reduced the incidence of hemorrhages when compared to electrical stunning. The results showed that stunning method had no effect on the amount of blood remaining in the veins of thigh muscles. The color scores did not differ between the two stunning systems for the thigh muscles.

Effect of Stunning Method on Liver Quality

The visual grading system did not show any difference between the livers from geese stunned with gas or electricity (Table 4). The hemorrhaging and color scores of livers from gas-stunned birds were not better than those of electrically stunned birds. As regards the liver weight loss caused by removal of veins and capillaries, stunning treatment had no significant effect on this parameter.

DISCUSSION

The geese stunned by electricity had an increased incidence of breast and thigh muscle hemorrhages compared to the gas-stunned birds. This finding is comparable with previous literature (Raj et al., 1990; Raj and Nute, 1995; Raj, 1998; Hoen and Lankhaar, 1999; Kang and Sams, 1999; Tserveni-Gousi et al., 1999; Uijttenboogaart, 1999). Hemorrhages in muscle tissues are considered major quality defects of poultry carcasses (Kranen et al., 2000). The electrical stunning method applied in this experiment was low frequency (50 Hz) treatment, although there is a tendency toward less hemorrhaging using high current

⁴HF-2000-EC Balance, A&D Instruments Ltd., Abingdon OX14 3YS, UK.

TABLE 4. Liver quality values following controlled atmosphere stunning (CAS) or electrical stunning (ES)

Parameter scored or measured	Stunning method	
	CAS	ES
Color ¹	2.09 ± 0.29 ^a	2.08 ± 0.31 ^a
Hemorrhaging ¹	2.17 ± 0.45 ^a	2.10 ± 0.43 ^a
Liver weight loss due to removal of blood vessels (%) ²	11.58 ± 1.08 ^a	10.94 ± 1.84 ^a

^aValues within a row with the same superscript are not significantly different ($P > 0.05$).

¹Values are means ± SD based on 150 observations (5 panelists, 10 samples, 3 replicates).

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

frequencies. Unlike electrical stunning, gas stunning did not have a direct effect on muscles. The convulsions observed after gas stunning were milder and, thus, caused less muscle hemorrhaging than the muscle contractions induced by direct stimulation during electrical stunning. In addition, Hillebrand et al. (1996) reported that shackled stunning procedures very often resulted in hemorrhages in thigh muscles. Shackling is painful (Sparrey and Kettlewell, 1994) and imposes considerable stress on birds, particularly turkeys (Raj, 1998) and geese because of their large sizes. The use of gas stunning can eliminate the stress associated with shackling before electrical stunning (Lambooj et al., 1999; Gerritzen et al., 2000). Wing flapping, which frequently occurs after head-only stunning, may also cause muscle hemorrhages.

As for meat color and the amount of blood in the veins, the use of electrical and gas stunning led to comparable scores with no significant differences in either case. According to Hillebrand et al. (1996), the amount of blood remaining in the muscles after the collapse of blood circulation is one of the main factors affecting carcass and meat color. The two stunning methods used in this experiment did not cause differences in the blood remaining in the veins and must be the reason why color scores did not differ significantly. These results support previous reports indicating no difference in the total blood loss after electrical or CO₂ stunning (Raj and Gregory, 1991; Kang and Sams, 1999). In this experiment, head-only water bath stunning was applied. Hillebrand et al. (1996) found that head-only stunning caused darker breast muscles than did whole-body stunning. Therefore, it is reasonable to believe that the use of whole-body stunning might have improved color scores to some extent.

Because of its sheltered position in the body, the liver is exposed to the direct effects of electrical and gas stunning to a lesser degree than are breast and thigh muscles, which may be one of the reasons that stunning method had no significant effect on liver quality.

Gas stunning is a definitely more humane method of immobilizing poultry than electrical stunning (Raj, 1998; Hoen and Lankhaar, 1999; Coenen et al., 2000; Gerritzen et al., 2000). Northcutt et al. (1998) found that CO₂ stunning and electrical stunning provided comparable turkey breast meat quality with no consistent differences, and Poole and Fletcher (1998) reached the same conclusion in connection with the use of a modified atmosphere stun-kill system (70% Ar + 30% CO₂) in broilers. The results

of the present study suggest that controlled atmosphere stunning of geese can reduce carcass and meat damage to some extent when compared to electrical stunning. However, it should be noted that the degree of reduction in carcass and meat damage largely depends on the electrical stunning treatment to which gas stunning is compared (Fletcher, 1999). The 75-mA electrical stunning applied in this experiment was intermediate between the high amperage treatment (125 mA) preferred by European poultry processors and the low amperage system (12 mA) used in the U.S. (Craig and Fletcher, 1995). The stunning amperage of 75 mA did not prove to be low enough to avoid considerable muscle hemorrhaging. Stunning time during electrical stunning also has an effect on meat quality by affecting postmortem muscle metabolism (Young et al., 1996; Young and Buhr, 1997). The stunning duration of 8 s applied also must have contributed to the meat quality defects observed after electrical stunning.

In conclusion, gas stunning produced higher quality goose meat, in terms of reduced muscle hemorrhaging, than electrical stunning and, therefore, might have commercial advantages. However, these benefits depend on the gas or electrical stunning systems used. In the case of liver geese, liver quality is of paramount importance, and controlled atmosphere stunning did not improve liver quality, compared to electrical stunning. The profit gained from the slight improvement in meat quality does not seem to be enough to cover the high price of a controlled atmosphere stunner.

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