Gas stunning and quality characteristics of turkey breast meat

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The effect of stunning method (gas vs. electrical) on some breast meat quality traits was evaluated on 128 breasts (P. major muscles) of 106 day-old female BUT-Big6 turkeys (8.9 kg live wt) reared under intensive conditions. The birds were processed on a commercial processing plant using either electrical (E) or gas (G) stunning system. The birds from E group were shackled and electrically stunned with a constant voltage of 44V pulsating DC, 500Hz, for 22 sec (average of 18-20 mA/bird), while G group birds were stunned by CO₂ exposure in their transport crates transiting through an underground chamber where birds encountered variable concentrations of carbon dioxide (from 10 to 60% CO₂ going from the top to the bottom level, respectively) for 8 min and subsequently shackled (Linco® system). After stunning all turkeys were killed and processed following the same standard procedures. For both E and G group, 16 breasts were boned at 20 min, 6, 8 and 24 h post mortem (n = 128) and the incidence of blood-engorged wing veins and breast blood spots were evaluated. After boning, the samples were immediately analysed for muscle temperature (only 20 min post mortem), pH, R-value, and colour (L*a*b*), while at 24 h post mortem all collected samples were also analysed for pHu, drip loss, cooking yield and Allo-Kramer shear values of cooked meat. The gas stunning resulted in a lower incidence of blood-engorged wing veins (1.6 vs. 14.1%) and blood spots on breast meat (18.8 vs. 31.3%) as well as a lower redness (a*, 2.92 vs. 3.34; P<0.01) and yellowness (b*, 2.85 vs. 3.36; P<0.05). Furthermore, gas stunning produced a lower breast muscle temperature (38.0 vs. 40.2°C; P<0.01) and a higher pH value (6.07 vs. 6.00; P<0.05) at 20 min post mortem as well as a higher cooking yield (84.5 vs. 83.3%; P<0.01). No differences were found in pHu, R-value, lightness, drip loss and shear values according to the stunning method. However, considering the interaction between the stunning method and boning time, it was observed that when carcasses are boned at 6 h post mortem (commercial boning time), gas stunning produces lower shear values (2.55 vs. 3.35 kg/g; P<0.05) of cooked breast meat than electrical stunning. In conclusion, turkey breast meat from gas stunned birds seems to have more favourable quality characteristics in comparison to breast meat of electrical stunned birds.

Keywords: gas stunning; carbon dioxide; turkey; breast meat; quality.

Introduction

Stunning before slaughter is a statutory requirement in the EU to induce unconsciousness and insensibility (inability to perceive stimuli) in animals, so that slaughter can be performed without avoidable fear, anxiety, pain, suffering and distress (EFSA, 2004). The most widely used stunning system of poultry is electrical stunning (Bilgili, 1999). However, under certain conditions, electrical stunning can result in carcass and meat defects like haemorrhages and broken bones. Increased incidences of carcass defects have been observed especially in some European countries where the use of high current during electrical stunning has been adopted to irreversibly stun (“stun-to-kill”) the birds before killing in order to insure animal welfare (Gregory and Wilkins, 1989; Fletcher, 1999). In addition to muscle hemorrhaging, high electrical stunning current can increase the incidence of broken
keels and wings, engorged wing veins, red wing tips and broken capillaries in the breast muscle mainly due to muscle super-contractions and subsequent haemorrhaging in muscle tissue caused by rupture of blood vessels and damage to muscle fibres (Northcutt et al., 1998; Savenije et al., 2002). The animal welfare issues and product quality problems due to the use of high current electrical stunning in Europe have conducted to develop alternatives to electric shock stunning such as gas stunning. Gas stunning has a high potential for humane stunning or stun-to-kill, it requires sophisticated and expensive technical equipment and has the main advantage in the fact that birds are exposed to a moderate handling stress only (EFSA, 2004). During gas stunning, the birds are exposed to gases which may induce either anesthesia or anoxia. Carbon dioxide is an anesthetic gas to induce rapid unconsciousness by altering the pH of the cerebrospinal fluid whereas argon and nitrogen are inert gases used to displace the air and cause unconsciousness through the lack of oxygen (Sams, 2001). One of the main advantage of gas stunning is represented by the fact that in some automated systems the birds can remain in transport crates from the time they are loaded at the farm until they are stunned, reducing both animal distressed and subsequent carcass defects (broken bones, haemorrhages, etc.) associated with unloading live birds from crates and handling them to the shackle line by their feet (Barbut, 2002). Besides haemorrhages and the other carcass defects, comparisons between electrical and gas stunning systems have outlined the existence of differences in muscle metabolism in early post mortem time as well as final meat quality traits (Raj, 1999 and 2004). However, contradictory results are sometimes reported, especially when different stunning conditions are compared. When argon is used as stunning gas, the induced anoxia has been reported to accelerate the rigor mortis development by determining a rapid decrease in pH caused by anoxic convulsions (wing flapping) during death that accelerate the post mortem utilization of ATP by the muscles and allow to bone the fillets at earlier post mortem times without impair the meat tenderness (Raj et al., 1991; Raj and Nute, 1995; Sams and Dzuik, 1999). However, Poole and Fletcher (1998) did not find any rigor accelerating benefits of a argon:carbon dioxide (70:30) modified atmosphere stun-kill system in comparison with low voltage stunning, and only minimal rigor acceleration when compared to a high current stunning. As regard to the use of carbon dioxide gas stunning in comparison with electrical stunning, it was observed that carbon dioxide stunning improves bleedout of broilers (Kotula et al., 1957) and determines a lower incidence of carcass defects such as broken bones and muscle haemorrhages as well as improved meat tenderness (Raj et al., 1990; Fleming et al., 1991; Veeramuthu and Sams, 1993; Raj, 1999). Other researches did confirm the reduced carcass damage in gas stunning but did not report a lower need of breast meat ageing before boning (Hirschler and Sams, 1993; Kang and Sams, 1999) or differences in the cooked breast meat quality after 24 h ageing (Northcutt et al., 1998). Poole and Fletcher (1998) speculated that the results obtained comparing gas and electrical stunning systems may be very different according to which type of electrical stunning is being used for comparison. Moreover, only few studies have been conducted under commercial conditions, and results obtained in small scale systems may not be confirmed in large processing plants.

A research was conducted in order to compare the breast meat quality traits of turkeys processed under commercial conditions and subjected to carbon dioxide or low voltage electrical stunning system.

Materials and methods

The research was carried out on 128 BUT-Big6 turkeys (106 day-old; 8.9 kg live wt) reared under intensive conditions. The birds were processed on a commercial processing plant using either electrical (E) or gas (G) stunning system. The birds from E group were shackled and electrically stunned with a constant voltage of 44V pulsating DC, 500Hz, for 22 sec (average of 18-20 mA/bird), while the G group birds were stunned by CO₂ exposure in their transport crates transiting through an underground chamber where birds encountered variable concentrations of carbon dioxide (from 10 to 60% CO₂ going from the top to the bottom level, respectively) for 8 min and subsequently shackled (Linco® system). After stunning all turkeys were killed and processed following the same standard procedures. For both E and G group, 16 breast (P. major) muscles were boned at 20 min, 6, 8, and 24 h post mortem (n = 128). On the carcasses boned at 20 min post mortem the temperature of P. major muscles was measured in the cranial part of the muscle. At the moment of boning, all carcasses were
evaluated for the presence of blood-engorged wing veins by cutting one wing per carcass. The incidence of engorged wing veins was subsequently calculated as percentage of considered carcasses. Furthermore it was subjectively evaluated the presence of blood spots on breast meat (bone side) surface and expressed as percentage of breast muscles showing visible blood spots. Immediately after boning (at 20 min, 6, 8, and 24 h post mortem), the breast fillets (P. major) were used for the measurement of pH, and R-value. Subsequently, the samples boned at 20 min, 6, and 8 h were stored at 2-4°C until 24 h post mortem and used (together with the samples obtained by boning the carcasses at 24 h post mortem) for the measurement of pHu, colour (L*a*b*), drip loss, cooking yield and Allo-Kramer shear values of cooked meat. Colour was determined using the CIELAB (CIE, 1976) colour values for lightness (L*), redness (a*), and yellowness (b*) using a reflectance colorimeter (Minolta Chroma Meter CR-300) and illuminant source C. The overall breast colour was evaluated averaging three colour measurements taken in the bone side muscle surface. The meat pH was determined according to the direct probe method by using a portable pH meter (HI98240; electrode FC230; Hanna Inst.). R-value was determined calculating the ratio of absorbance at 250 and 260 nm as described by Honikel and Fischer (1977). Drip loss was determined by measuring the loss of water from a muscle sample of about 80 g kept suspended in a glass box at 2-4°C for 48 h and expressed as the percentage of weight loss during storage. Cooking yield was determined by cooking breast meat samples of about 80 g on a convection oven at 180°C to an endpoint temperature of 80°C. Cooking yield was subsequently calculated as percentage of initial sample weight. Shear values were determined using a TA-Hdi® Texture Analyser equipped with an Allo-Kramer shear device according to the procedure described by Papinaho and Fletcher (1996). AK shear values were reported as kilograms shear per gram of meat.

The data of engorged wing veins and breast with blood spots were analyzed by chi-square test. The other data (muscle temperature, L*, a*, b*, pH, R-value, drip loss, cooking yield and shear values) were analyzed by using one-way ANOVA testing the effect of stunning method (gas vs. electrical) and means were separated using the Duncan’s multiple range test.

**Results and discussion**

In figure 1 the incidence of turkey carcasses with engorged wing veins, breasts with blood spots, and breast muscle (P. major) temperature at 20 min post mortem are shown. Gas stunning determined a significant lower incidence of blood-engorged wing veins (1.6 vs. 14.1%; P<0.01) and a tendency to show a lower percentage of breast with blood spots (18.8 vs. 31.3%). These results are consistent with previous researches indicated that carbon dioxide stunning produces a decreased incidence of carcass defects, such as broken clavicles and breast, thigh, and shoulder hemorrhages, compared to electrical stunning (Fleming et al., 1991; Hirschler and Sams, 1993; Kang and Sams, 1999; Raj, 1999). One of the main advantages of gas stunning is represented by the fact that in automated systems, like the one adopted in this study, the birds remain in transport crates until they are stunned. By this way, they were shackled while unconscious and very malleable, minimizing problems associated with animal struggling and wing flapping. This might explain also the results for breast muscle temperature at 20 min post mortem which was lower in birds subjected to gas in respect to electrical stunning (38.0 vs. 40.2°C; P<0.01). The higher temperature in E birds can be related to an accelerated muscle metabolism due to the struggling and wing flapping which occured during hanging and stunning.

The figure 2 shows the influence of stunning system on pH decline and R-values of breast muscles. At 20 min post mortem, the electrically stunned birds exhibited a lower pH than gas stunned turkeys (6.00 vs. 6.07; P<0.05) indicating an accelerated post mortem glycolysis compared to G birds. This result is consistent with the higher body temperature observed in E turkeys (Figure 1). Kang and Sams (1999) also reported that CO2 stunning determined significantly higher broiler breast meat pH values at 1 h post mortem. The authors speculated that more severe and stronger muscular contractions induced by electrical stunning than carbon dioxide exposure could be responsible for the lower observed muscle pH. Despite the results for pH, the R-values measured at varying post mortem times (Figure 2) did not differ between groups. The R-value is the ratio of low energy inosine to high energy adenosine compounds and represents an indirect measure of adenosine triphosphate (ATP) depletion in the muscle. During **rigor mortis** development, ATP in the muscle is depleted and R-value increases.
The results shown in figure 2 indicate that the stunning system did not modify the rate of post mortem ATP depletion. On the contrary, Kang and Sams (1999) reported that CO₂ stunning in broilers, in respect with electrical stunning, produced significantly higher R-values of breast meat at 2 and 6 h post mortem indicating an acceleration in the rigor mortis development.

**Figure 1** The influence of stunning system on the incidence of turkey carcasses with engorged wing veins (n=64 per group), breasts with blood spots (n=64 per group), and muscle (P. major) temperature at 20 min post mortem (n=16 per group).

<table>
<thead>
<tr>
<th></th>
<th>Carcasses with blood engorged wing veins (%)</th>
<th>Breasts with blood spots (%)</th>
<th>P. major muscle temperature at 20 min post mortem (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical</td>
<td>A 31.3</td>
<td>B 18</td>
<td>A 40.2</td>
</tr>
<tr>
<td>Gas</td>
<td>A 16</td>
<td>B 18</td>
<td>B 38.0</td>
</tr>
</tbody>
</table>

**Figure 2** Influence of stunning system on pH decline and R-values in turkey breast muscles (n=16 per group per post mortem time).

As regard to the meat quality traits measured at 24 h post mortem (Table 1), no differences were found in pHu and drip loss, whereas cooking yield from gas stunned turkeys was higher than that obtained with electrical stunning (84.5 vs. 83.3%; P<0.01). This latter result can be related to a higher protein denaturation occurred in breast meat from electrically stunned turkeys due to the higher muscle temperature and lower pH during early post mortem time (20 min). Furthermore, the colour of breast meat from the G group was less red (2.92 vs. 3.34; P<0.01) and less yellow (2.85 vs. 3.36; P<0.05). The lower meat redness in gas stunned birds is consistent with the lower incidence of breasts with blood spots and can be associated to the reduced wing flapping during hanging and stunning. Previous studies reported higher values of breast meat redness (a*) from electrically stunned birds in respect with CO₂ stunning in both turkeys (Fleming et al., 1991) and broilers (Raj et al., 1990). However other authors did not confirm this result (Northcutt et al., 1998). No significant difference was observed by
considering the overall mean shear values of cooked meat (3.60 vs. 4.03 kg/g for G and E groups, respectively; data not shown) as previously found by Northcutt et al. (1998). However, considering the different post mortem boning times (Figure 3), it was found that at 6 h, which represents the commercial boning time adopted in the slaughter plant where the research has been carried out, gas stunning produced a lower shear values of cooked meat (2.55 vs. 3.35 kg/g; P<0.05) than electrical stunning. Moreover, shear values measured at 6 h on the G group were very close to that observed at 24h post mortem which means no need of further ageing.

Table 1 Quality traits (mean ± sem) of turkey breast meat obtained with electrical or gas stunning.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Electrical</th>
<th>Gas</th>
</tr>
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<tbody>
<tr>
<td>n.</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>pHu</td>
<td>5.81 ± 0.01</td>
<td>5.82 ± 0.01</td>
</tr>
<tr>
<td>drip loss (%)</td>
<td>0.87 ± 0.04</td>
<td>0.80 ± 0.03</td>
</tr>
<tr>
<td>cooking yield (%)</td>
<td>83.3 ± 0.33B</td>
<td>84.5 ± 0.33A</td>
</tr>
<tr>
<td>lightness (L*)</td>
<td>49.32 ±0.42</td>
<td>48.92 ± 0.37</td>
</tr>
<tr>
<td>redness (a*)</td>
<td>3.34 ± 0.11A</td>
<td>2.92 ± 0.10B</td>
</tr>
<tr>
<td>yellowness (b*)</td>
<td>3.36 ± 0.17a</td>
<td>2.85 ± 0.17b</td>
</tr>
</tbody>
</table>

A, B = P<0.01; a, b = P<0.05.

Figure 3 Influence of stunning system on shear values of cooked turkey breast meat boned at 20 min, 6, 8, and 24 h post mortem (n=16 per group per post mortem boning time).

In conclusion, compared with electrical stunning, gas stunning determined a lower incidence of engorged wing veins and a tendency to a lower prevalence of breast with blood spots. Moreover, the breast meat from gas stunned birds showed a less red colour and exhibited a lower muscle temperature and higher pH at 20 min post mortem as well as a higher cooking yield. Finally, when the boning was conducted at 6h post mortem (commercial boning time), gas stunning determined a lower shear values of cooked breast meat.

References


