Anim. Res. 52 (2003) 383–397

DOI: 10.1051/animres:2003024

Original article

The influence of current parameters during the water-bath stunning of overfed geese (*Anser anser*) on blood loss and on fatty liver and meat downgrading

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(Received 28 August 2002; accepted 23 June 2003)

Abstract — Three experiments were carried out to study the effect of current intensity, stunning duration and current frequency during the water-bath stunning of overfed geese, on blood loss and fatty liver downgrading. In experiment 1, 259 geese and ganders were stunned for 5 s with a sinusoidal alternating current (AC) of 50 Hz at 30, 50 or 70 mA. In experiment 2, a sinusoidal AC (50 Hz, 50 mA) was applied for 2, 5 or 13 s on 223 geese and ganders. In experiment 3, 180 geese and ganders were stunned with a sinusoidal AC (50 mA, 5 s) at 50, 300, 600 or 1200 Hz. In each experiment, a control group was slaughtered without stunning. In experiment 1, the stunned birds showed less blood loss than the control ones. Stunning increased the incidence of pink/red coloration of liver lobe tips and the incidence of petechial hemorrhages on breast muscle. Geese showed an increased incidence of petechial hemorrhages on fatty liver with increased current intensity. In experiment 2, the control birds showed higher blood loss than stunned birds. Increasing stunning duration decreased the paleness (L*) of the liver, enhanced its redness (a*) and increased the incidence of petechial hemorrhages in the breast muscle of the ganders. Stunning at high frequency (1200 Hz, experiment 3) decreased the pink/red coloration of liver lobe tips in the ganders and the incidence of petechial hemorrhages on the breast muscle in both sexes. Overall, the present data showed a detrimental effect of stunning on blood loss and fatty liver downgrading, regardless of stunning conditions.

goose / fatty liver / electrical stunning / blood loss / product downgrading

Résumé — **Influence des paramètres du courant au cours de l'électronarcose en bain électrifié des oies gavées sur la qualité de la saignée et l'altération des foies gras.** Trois expériences ont été réalisées pour étudier l'effet de l'intensité, de la durée d'application et de la fréquence du courant

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d'électronarcose en bain électrifié sur la qualité de la saignée et les qualités de présentation des foies gras chez l'oie gavée. Dans l'expérience 1, 259 mâles et femelles étaient étourdis individuellement pendant 5 s par un courant alternatif sinusoïdal de 50 Hz à 30, 50 ou 70 mA. Dans l'expérience 2, un courant alternatif sinusoïdal (50 Hz, 50 mA) était délivré pendant 2, 5 ou 13 s sur 223 mâles et femelles. Dans l'expérience 3, 180 mâles et femelles étaient étourdis individuellement avec un courant alternatif sinusoïdal (50 mA, 5 s) à 50, 300, 600 ou 1200 Hz. Dans chaque expérience, un lot témoin était abattu sans étourdissement. Dans l'expérience 1, les animaux étourdis présentaient une saignée moins abondante que les témoins. L'électronarcose augmentait la fréquence de la coloration rose/rouge des pointes des lobes des foies gras ainsi que la fréquence des pétéchies sur les magrets. Chez les femelles, la fréquence des pétéchies sur les magrets augmentait avec l'intensité du courant. Dans l'expérience 2, la saignée était plus abondante chez les témoins que chez les animaux étourdis. L'augmentation de la durée d'application du courant réduisait la pâleur des foies (L*) et augmentait leur teinte rouge (a*) ainsi que la fréquence des pétéchies dans les magrets chez les mâles. L'éléctronarcose à fréquence élevée (1200 Hz, expérience 3) réduisait la coloration rose/rouge des foies gras chez les mâles et la fréquence des pétéchies dans les magrets chez les deux sexes. Ces résultats montrent l'effet défavorable de l'étourdissement en bain électrifié sur l'efficacité de la saignée et les qualités de présentation des foies gras, quelles que soient les conditions d'électronarcose.

oies / foie gras / électronarcose / saignée / qualités

1. INTRODUCTION

The production of overfed geese for fatty liver consumption has increased in France during the past years (+15% from 1999 to 2000) and has reached about 1 million overfed animals. A large proportion of birds (800 000) are slaughtered under commercial conditions. Downgrading of fatty liver, due to gross appearance defects, is a crucial commercial issue since this product has a strong added value. The main appearance defects reported by processing plants are the overall redness of the liver, which is thought to be highly dependent on the efficiency of blood loss, the presence of hematoma and petechial hemorrhages and the red color of the lobe tips. Although the etiology of these defects has not been studied in detail, several empiric observations, carried out under commercial conditions, suggest a major role of the stunning process (Leprettre, unpublished observations). In France, overfed geese are usually stunned individually in a water bath using an AC 50 Hz sine wave current, but the electrical stunning conditions are not standardized in terms of intensity and/or duration. For other avian species such as broilers or turkeys, high currents are required for an efficient stun, i.e. loss of consciousness [4, 10]. However, increasing the current intensity leads to a higher incidence of carcass downgrading ([2] for broilers and [3] for turkeys). In turkeys, increasing the current frequency reduces the incidence of stunning-induced carcass defects [15] and improves blood loss [9].

The incidence of current parameters on product quality has never been investigated in overfed geese. Thus, three experiments were carried out to study the effect of current intensity, stunning duration and current frequency on blood loss and fatty liver downgrading.

2. MATERIALS AND METHODS

2.1. Animals, breeding and overfeeding

A total of 662 geese and ganders (*Anser anser*) from the French Landes grey breed were used in three experiments. The animals were raised at the Station of Goose Breeding (Coulaures, France) until the age of 12 (experiments 1 and 2) or 17 weeks (experiment 3), following standardized practices [8]. The animals were then overfed in collective pens (10–12 animals per pen; pen size 3 × 1 m) during 19 (experiments 1 and 2) or 18 days (experiment 3). Overfeeding was achieved by the distribution of a soaked-corn mixture (grain-flour; 42–58) in four meals per day, using an hydraulic machine. The quantity distributed was adapted to the ingestion capacity of each animal.

2.2. Stunning and slaughter

For each experiment, the animals were slaughtered in the experimental abattoir of the Station of Goose Breeding (Coulaures, France), over two days for experiment 1, and over one day for experiments 2 and 3. The last meal was given 8 h (experiments 1 and 2) or 12 h (experiment 3) before slaughter. The geese were suspended head downwards from a shackle and individually stunned in a water-bath by immersion of the head and upper neck, according to the treatments described below. In each experiment, a control group was slaughtered without stunning.

2.2.1. Experiment 1 – Effect of current intensity (n = 259)

A voltage generator was used to deliver a sinusoidal AC current of 85, 130, or 170 V (50 Hz) during 5 s. The generator gave the effective tension (U) and intensity (i) on the circuit during the electric load and this information was recorded for each animal. Previous observations on this circuit showed that such voltages were associated with average intensities of 30, 50 and 70 mA, respectively. The impedance (Z) was calculated as $Z = U/i$, and expressed as Ω.

2.2.2. Experiment 2 – Effect of stunning duration (n = 223)

The same generator as above was used to deliver a sinusoidal AC current of 50 Hz, 130 V (corresponding to an average intensity of 50 mA) during 2, 5 or 13 s. Stunning durations of 2 s and 13 s correspond to the extreme values which have been observed under commercial conditions (Leprettre, unpublished observations).

2.2.3. Experiment 3 – Effect of current frequency (n = 180)

A constant current stunner, designed and provided by the Silsoe Research Institute (Silsoe, Bedfordshire, UK) was used to deliver an AC sinusoidal current of 50 mA (5 s) at 50, 300, 600 or 1200 Hz. The tension applied on the circuit was not monitored by the generator. Thus, the tension values were not available for experiment 3.

At 10 s after the end of the stun, a bilateral section of the carotid arteries and the jugular veins was manually performed. Bleeding was allowed for 3 min before entering the scalding tank.

2.3. Measurements at slaughter

Blood was collected in a plastic bag suspended around the neck of the animal. The amount of blood loss was measured by weighing the blood obtained after 3 min of bleeding. In order to express blood loss relative to lean weight, blood losses were calculated as blood weight/live weight immediately before overfeeding (expressed as %).

The carcasses were then eviscerated (25–30 min post mortem). The fatty liver was collected, weighed and the liver color was measured as trichromatic coordinates (L*, a*, b*) using a CR 300 Minolta chromameter. The appearance defects of fatty livers usually reported under industrial conditions were subjectively scored. These included petechial hemorrhages and red color of the lobe tips. *Petechiae* were recognized as small pin-point like bloodspots at the surface of the liver, originating from capillary damages. They were scored as 1 = absence of the defect or 2 = presence of the defect. The coloration of the lobe tips was subjectively scored as 1 = normal; 2 = pink coloration; 3 = red coloration, except in experiment 3 where a red coloration was never observed and thus, color was scored as 1 = normal and 2 = pink. At 24 h post mortem, the carcasses were cut and the breast muscles were harvested. The incidences of petechial hemorrhages on breast muscle, red wing tips and fracture of the proximal end of the humerus bone (*caput humeri*) were recorded as presence or absence. Under commercial conditions, the fracture of the proximal end of the humerus is often reported as a main appearance defect induced by water-bath stunning of overfed waterfowls.

2.4. Statistical analysis

For numerical data, analyses of variance were performed using the GLM (General Linear Model) procedure of SAS [13]. The model included the main effect of slaughter series (experiment 1 only, 2 levels), sex, appropriate treatment (current intensity, experiment 1; stunning duration, experiment 2; current frequency, experiment 3) and first order interactions. When the variance analysis revealed a significant effect, the differences between groups were tested using the Duncan multiple range test. Subjective score data were treated by non parametric analysis of variance, using the "NPAR1WAY" procedure of SAS [13]. Where appropriate, means were compared using the Wilcoxon non parametric test for paired-mean comparison.

The results from variance analysis were considered as significant when *P* values were lower than 0.05, and as trends when *P* values ranged from 0.05 to 0.10.

3. RESULTS

3.1. Experiment 1 – Effect of current intensity

As shown in Table I, all production traits differed significantly according to sex. Geese showed significantly lower live weight before and after overfeeding, lower weight gain during over-feeding and lower liver weight, than ganders. Liver weight differed significantly between slaughter series (see Tab. I for the results of variance analysis): 918 ± 19 and 829 ± 15 g for series 1 and 2, respectively. Blood loss was significantly higher in geese than in ganders (Tab. II).

Increasing current intensity led to a significant decrease in impedance (Tab. II). Electrical stunning significantly reduced blood loss, compared to no stunning. Trichromatic coordinates of fatty liver differed significantly between slaughter series (see Tab. II for the results of variance analysis): values for L*, a* and b* were 67.1 ±

Table I. Effect of series and sex on production traits in Experiment 1.

	Sex			Significance level[1]		
	Ganders (*n = 137*)	Geese (*n = 122*)	SE	*Series*	*Sex*	*Series × Sex*
LW before overfeeding (kg)	5.75^a	5.34^b	*0.44*	$P = 0.09$	***	$P = 0.08$
LW after overfeeding (kg)	8.60^a	8.31^b	*0.51*	NS	***	NS
Weight gain (kg)	2.97^a	2.85^b	*0.28*	NS	**	NS
Liver weight (g)	906^a	837^b	*191*	***	***	$P = 0.08$

[1] Significance level of the effect, ***: $P < 0.001$; **: $P < 0.01$; NS: $P > 0.10$; LW: live weight.
[ab] Within a row, means lacking a common superscript differ significantly at $\alpha = 0.05$.

Table II. Effect of sex and stunning current intensity (50 Hz AC, 5 s) on electrical parameters, blood loss and trichromatic coordinates of the fatty liver in experiment 2.

	Sex		Current intensity					Significance level[1]					
	Ganders *(n = 137)*	Geese *(n = 122)*	No stun *(n = 65)*	30 mA *(n = 68)*	50 mA *(n = 65)*	70 mA *(n = 61)*	**SE**	*Slaughter Series*	*Sex*	*Intensity*	*Series × Sex*	*Series × Intensity*	*Sex × Intensity*
Current tension (V)	131	125	-	85^{c}	132^{b}	171^{a}	*12.5*	NS	NS	***	NS	NS	NS
Current level (mA)	48.5	47.9	-	29.9^{c}	48.5^{b}	68.4^{a}	*4.2*	NS	NS	***	NS	NS	NS
Impedance (Ω)	2759	2658	-	2861^{a}	2739^{b}	2509^{c}	*330*	NS	NS	***	NS	NS	NS
Blood loss (%)	5.57^{b}	5.82^{a}	6.03^{a}	5.55^{b}	5.61^{b}	5.55^{b}	*0.52*	NS	***	***	NS	NS	NS
Liver color													
L*	66.3	66.7	67.1	66.3	66.4	66.2	*2.7*	***	NS	NS	NS	NS	NS
a*	10.2	10.4	9.9	10.6	10.2	10.4	*1.5*	**	NS	NS	NS	NS	NS
b*	23.9	23.4	23.9	23.0	24.1	23.8	*2.8*	**	NS	NS	NS	NS	NS

[1] Significance level of the effect, ***: $P < 0.001$; **: $P < 0.01$; NS: $P > 0.10$; SE: standard error.
[abc] Within a row and for a given factor (sex or current intensity), means lacking a common superscript differ significantly at $\alpha = 0.05$.

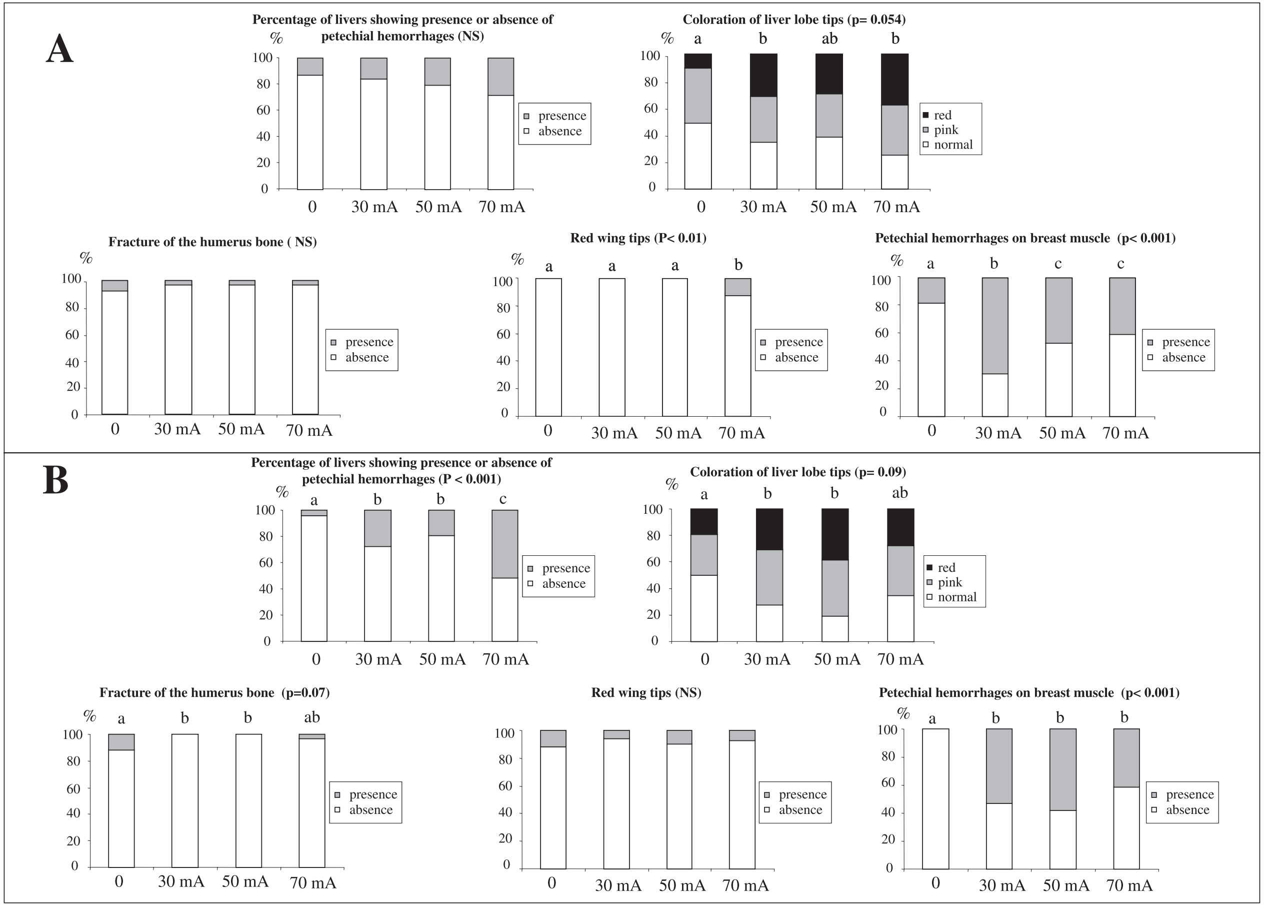

Figure 1. Experiment 1: Influence of current intensity during the water-bath stunning of overfed ganders (A) and geese (B) on the incidence of various appearance defects (different letters indicate a significant difference in the distribution of scores between the stunning treatments; 0: no stunning).

0.2, 10.0 ± 0.1 and 24.2 ± 0.3, and 66.0 ± 0.2, 10.5 ± 0.1 and 23.3 ± 0.2, for series 1 and 2, respectively.

In ganders, the incidence of petechial hemorrhages on the liver was not significantly affected by current intensity (Fig. 1A). However, current intensity affected the incidence of red coloration of lobe tips ($P = 0.054$): 30 mA- and 70 mA-stunned ganders showed a significantly higher incidence of this defect than non stunned birds, 50 mA-stunned ganders being intermediate. Twelve percent of the 70 mA-stunned ganders showed red wing tips whereas this defect was not detected in any of the other treatments. Stunned ganders showed a significantly higher incidence of petechial hemorrhages in breast muscle than non stunned birds. Within stunned ganders, the incidence of this defect was significantly higher in 30 mA- than in 50 mA- and 70 mA-stunned animals. The incidence of humerus bone fracture was low (< 8%) and did not depend on the stunning treatment.

In geese, the incidence of petechial hemorrhages in the liver was significantly higher in stunned compared to non stunned birds (Fig. 1B). Within stunned geese, the 70 mA treatment was associated with the highest incidence of this defect. The red coloration of liver lobe tips was more present ($P = 0.09$) in 30 mA- and 50 mA-stunned than in non stunned geese, the 70 mA-stunned animals being intermediate. Petechial hemorrhages in the breast muscle were detected in all stunning treatments with a similar incidence, whereas the non stunned geese did not show this defect. Non stunned geese showed a higher incidence of humerus bone fracture (11.5%; $P = 0.07$) than 30 mA- and 50 mA-stunned birds (absence of the defect), the 70 mA-stunned geese being intermediate (3%).

3.2. Experiment 2 – Effect of stunning duration

Ganders showed significantly higher live weights before and after overfeeding than females (Tab. III). Current tension differed significantly between sexes (Tab. IV). There was, however, a significant "sex × stunning duration" interaction for this trait (see Tab. IV, for the results of variance analysis): the difference in the current tension between sexes was significant only in the 2 s and 13 s stunning treatments (not shown

Table III. Effect of sex on production traits in experiments 2 and 3.

	Ganders	Geese	SE	Significance level[1]
Experiment 2	*(n = 131)*	*(n = 92)*		
LW before overfeeding (kg)	6. 11	5.63	*0.42*	***
LW after overfeeding (kg)	9.24	8.80	*0.58*	***
Weight gain (kg)	3.14	3.17	*0.32*	NS
Liver weight (g)	961	936	*220*	NS
Experiment 3	*(n = 89)*	*(n = 91)*		
LW before overfeeding (kg)	5.87	5.13	*0.26*	***
LW after overfeeding (kg)	8.83	8.17	*0.32*	***
Weight gain (kg)	2.97	3.04	*0.24*	*
Liver weight (g)	843	896	*193*	$P = 0.07$

[1] Significance level of the effect of sex, ***: $P < 0.001$; **: $P < 0.01$; *: $P < 0.05$; NS: $P > 0.10$; LW: live weight.

Table IV. Effect of sex and stunning duration (50 Hz AC, 130 V) on electrical parameters, blood loss and trichromatic coordinates of the fatty liver in experiment 2.

	Sex		**Stunning duration**					**Significance level**[1]		
	Ganders (*n* = 131)	Geese (*n* = 92)	No stun (*n* = 56)	2 s (*n* = 56)	5 s (*n* = 56)	13 s (*n* = 55)	**SE**	*Sex*	*Stunning duration*	*Sex × Stunning duration*
Current tension (V)	129.7^{a}	129.0^{b}	-	129.3	129.7	129.2	*1.22*	***	$P = 0.07$	*
Current level (mA)	47.2	47.1	-	46.7	47.0	47.9	*5.52*	NS	NS	NS
Impedance (Ω)	2783	2773	-	2818	2792	2725	*329*	NS	NS	NS
Blood loss (%)	5.50^{b}	5.58^{a}	5.83^{a}	5.42^{b}	5.47^{b}	5.42^{b}	*0.49*	*	***	NS
Liver color										
L*	66.7^{b}	67.7^{a}	67.8^{a}	67.8^{a}	66.6^{b}	66.2^{b}	*2.8*	**	*	NS
a*	10.5^{a}	9.8^{b}	9.6^{c}	9.9^{bc}	10.5^{ab}	10.9^{a}	*1.9*	**	**	NS
b*	26.5	25.8	27.0^{a}	25.1^{b}	26.0^{ab}	26.8^{a}	*3.3*	NS	*	NS

[1] Significance level of the effect, ***: $P < 0.001$; **: $P < 0.01$; *: $P < 0.05$; NS: $P > 0.10$.
[abc] Within a row and for a given factor (sex or stunning duration), means lacking a common superscript differ significantly at $\alpha = 0.05$.

in table). Blood loss was significantly higher in geese than in ganders. The fatty livers from the geese were significantly paler and less red than those from the ganders.

Blood loss was significantly affected by the stunning treatment; stunned birds showed a lower blood loss than non stunned ones. The trichromatic coordinates measured on the liver were significantly affected by stunning treatment. The luminance (L*) decreased and the redness (a*) increased, with increasing stunning duration. The yellowness (b*) differed significantly among the treatments but no clear relationship with stunning duration could be drawn up.

In ganders, petechial hemorrhages on breast muscle increased with stunning duration (Fig. 2A): non stunned birds did not show this defect and its incidence was significantly lower in 2 s-stunned compared to 5 s- and 13 s-stunned ganders. The incidence of red wing tips was high (> 60%) and not affected by stunning treatment. No humerus bone fracture could be detected in any of the stunning treatment (results not shown in the figure).

Among the subjectively assessed defects, only the petechial hemorrhages on breast muscle were significantly affected by stunning treatment in geese (Fig. 2B): the defect was detected in stunned birds but it was absent in non stunned geese. No humerus bone fracture could be detected in any of the stunning treatments (results not shown in the figure).

3.3. Experiment 3 – Effect of stunning current frequency

All production traits were significantly affected by sex (Tab. III): the geese showed lower live weight before and after overfeeding, higher weight gain during overfeeding and they tended (P = 0.07) to produce heavier fatty livers than the ganders.

Blood loss was significantly higher in the geese than in the ganders (Tab. V). Fatty livers from the geese were significantly paler and less yellow than those from the ganders. Blood loss and liver color were not significantly affected by stunning treatment.

Stunning treatment affected (P = 0.06) the coloration of liver lobe tips in ganders (Fig. 3A): the incidence of pink color increased from non stunned to 300 Hz-stunned birds, and decreased until stunning at 1200 Hz where the percentage of pink lobe tips did not differ significantly from that of non stunned birds. Petechial hemorrhages on the breast muscle of the ganders were significantly affected by stunning treatment but a clear relationship between the current frequency and the incidence of this defect could not be clearly shown.

In geese, the non stunned birds did not show any petechial hemorrhages in the liver, whereas the incidence of this defect ranged from 39 to 48% in stunned animals, regardless of current frequency (Fig. 3B). The highest incidence of petechial hemorrhages in breast muscle was observed for the geese stunned with a 50 Hz current. It is worth noting that the geese stunned with a 1200 Hz current did not show this defect, as was the case in non stunned birds.

4. DISCUSSION

4.1. Effect of electrical stunning versus no stunning

In experiment 1 and 2, stunned birds lost less blood during the first 3 min post mortem than non stunned birds. Similar observations have been reported in chickens [6, 7] where birds killed by severing the carotid artery and the jugular vein on one side of the neck lost more blood during 3 min than birds killed in the same way after electrical stunning. In fowl, stunning before venesection has been shown to induce

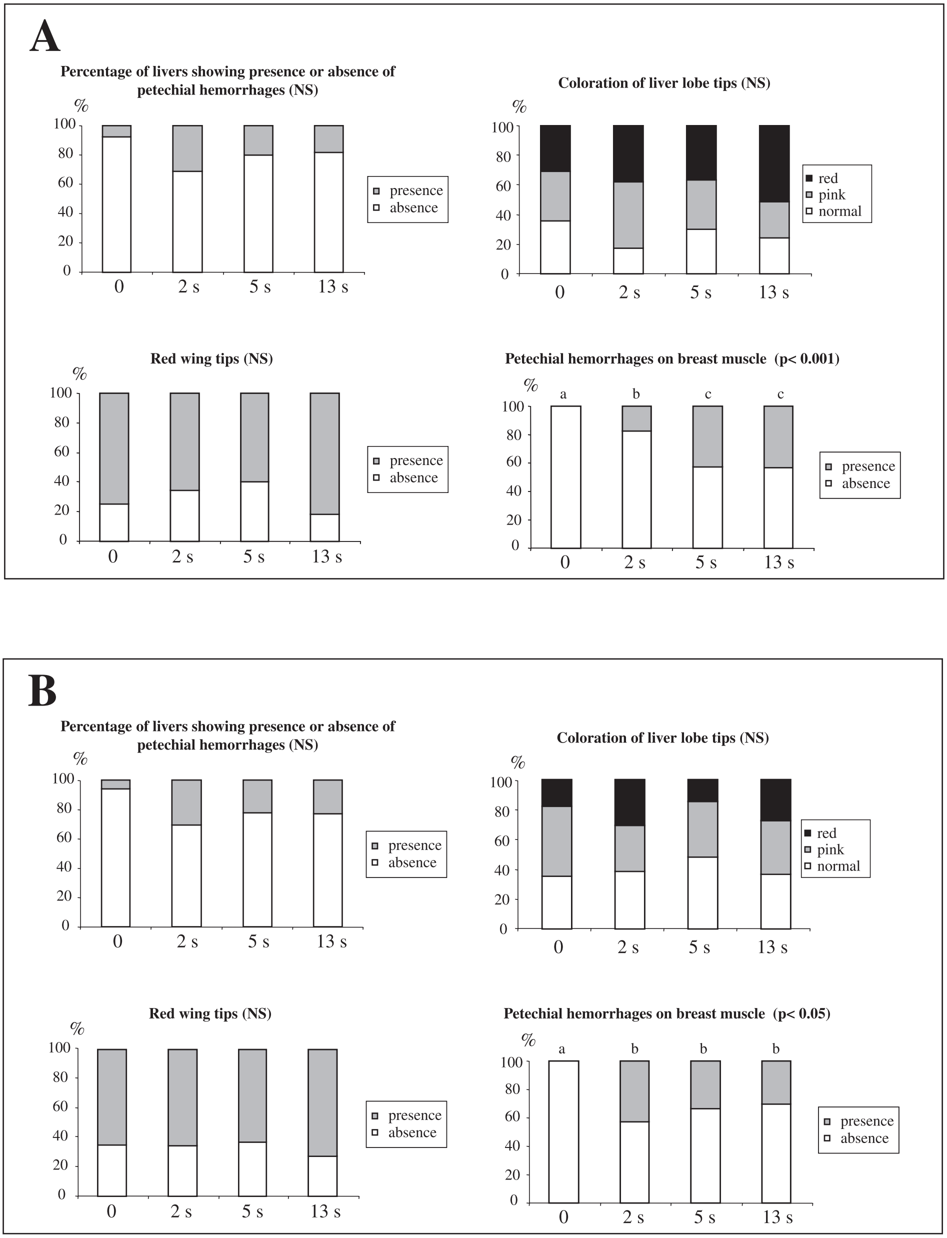

Figure 2. Experiment 2: Influence of water-bath stunning duration of overfed ganders (A) and geese (B) on the incidence of various appearance defects (different letters indicate a significant difference in the distribution of scores between the stunning treatments; 0: no stunning).

Table V. Effect of sex and stunning current frequency (50 mA AC, 5 s) on electrical parameters, blood loss and trichromatic coordinates of the fatty liver in Experiment 3.

	Sex		**Stunning current frequency**					**SE**	**Significance level**[1]		
	Ganders *(n = 89)*	Geese *(n = 91)*	No stun *(n = 37)*	50 Hz *(n = 43)*	300 Hz *(n = 39)*	600 Hz *(n = 34)*	1200 Hz *(n = 27)*		*Sex*	*Current frequency*	*Sex × Current frequency*
Blood loss (%)	5.54^{b}	5.85^{a}	5.79	5.70	5.69	5.68	5.61	*0.48*	***	NS	NS
Liver color											
L*	68.5^{b}	69.2^{a}	68.6	69.0	68.9	68.6	69.2	*2.2*	*	NS	NS
a*	8.1	7.9	8.1	7.9	8.0	8.1	7.9	*1.2*	NS	NS	NS
b*	28.4^{a}	26.7^{b}	27.8	27.0	27.4	27.4	28.1	*2.9*	***	NS	NS

[1] Significance level of the effect, ***: $P < 0.001$; **: $P < 0.01$; *: $P < 0.05$; NS: $P > 0.10$.
[abc] Within a row and for a given factor (sex or current frequency), means lacking a common superscript differ significantly at $\alpha = 0.05$.

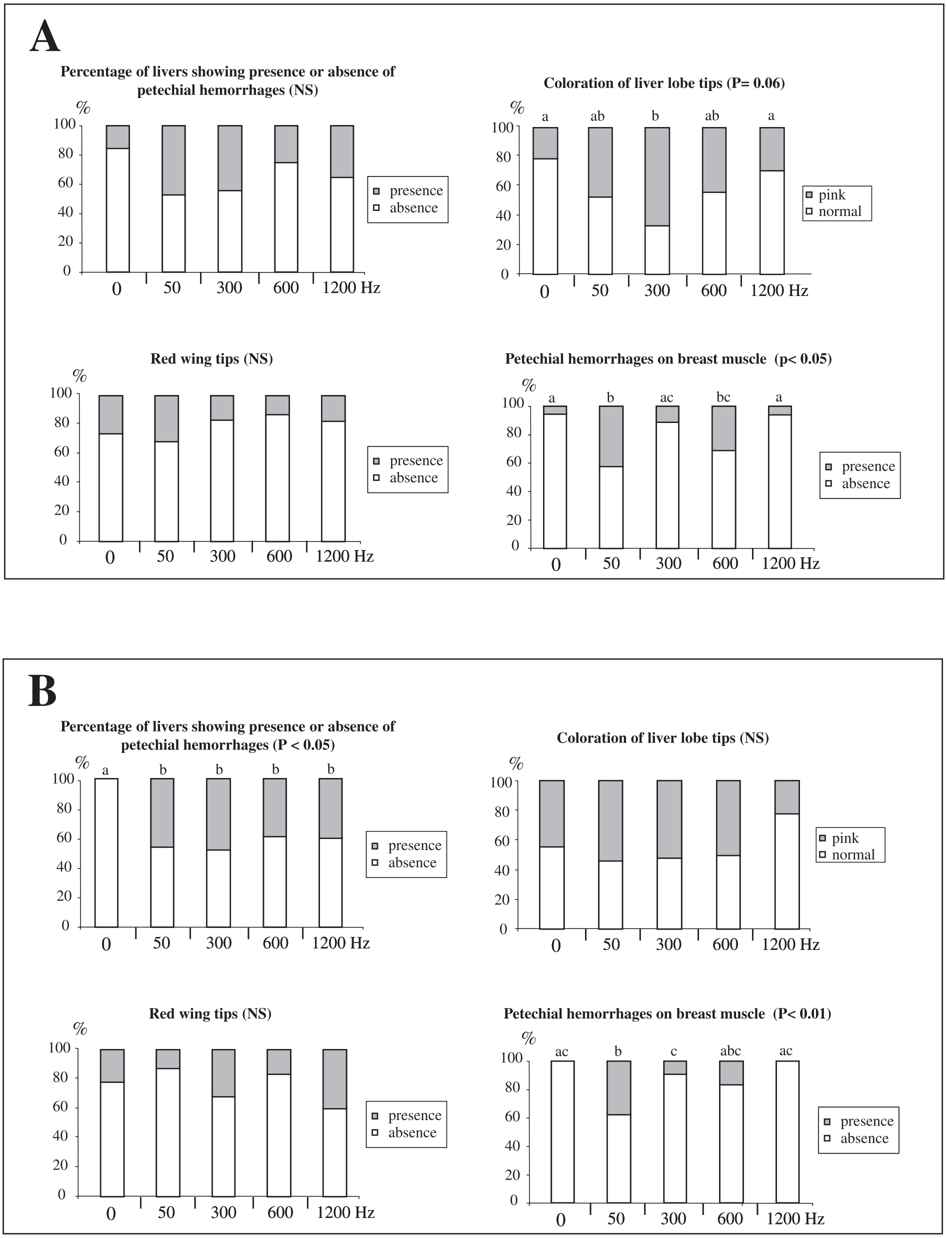

Figure 3. Experiment 3: Influence of current frequency during the water-bath stunning of overfed ganders (A) and geese (B) on the incidence of various appearance defects (different letters indicate a significant difference in the distribution of scores between the stunning treatments; 0: no stunning).

a drastic fall in heart rate and a bradycardia [12]. This physiological response, associated with local muscle contraction induced by the electrical field, could explain the effect of stunning on blood loss, at least in the earlier stage of bleeding. It should, however, be mentioned that in experiment 3 (the effect of current frequency), such an effect was not observed. Other environmental and technological factors may affect the bird's response to stunning in terms of bleeding. Indeed, under other experimental conditions, electrical stunning has been shown to increase blood loss in chickens, as compared to no stunning [1].

In general, vital organs appear to retain the largest amount of blood during bleeding [6]. Kotula and Helbacka [6] also showed that the quantity of blood retained in chicken parts was the most important in the liver. If the same phenomenon occurs in force-fed waterfowls, altered blood loss after electrical stunning may increase the appearance defect of fatty liver. This effect was not systematically demonstrated in the three experiments, when considering the color assessed instrumentally (trichromatic coordinates), except in experiment 2 where birds stunned for 5 or 13 s, showed a higher liver redness than non stunned ones. The same observation holds true when one considers the color of liver lobe tips assessed subjectively. The effect of stunning, compared to no stunning, was not systematic and when significant, it depended upon sex or stunning conditions. This aspect will be discussed in the next section.

The most consistent effect of electrical stunning, among the various appearance defects, was found for the incidence of petechial hemorrhages on breast muscle. This is a well known detrimental effect of stunning, and more specifically, of poultry water-bath stunning (for a review see Raj [10]). Electrical stunning increased the incidence of liver petechial hemorrhages, only in females and in experiments 1 and 3. It is somewhat difficult to explain the lack of an effect in experiment 2 since, compared to experiment 1, the age of the birds, the length of overfeeding, the duration of food withdrawal before slaughter were the same, and the stunning was carried out with the same system. However, the geese used in experiment 2 were heavier and their livers at the end of the overfeeding period were much heavier (961 g) than in experiment 1 (837 g) and 3 (896 g). A link between the production performance, i.e. fatty liver weight, and the sensitivity of the liver to electrical stunning could be evoked, but this deserves further investigation.

4.2. Effect of electrical stunning conditions

The present data demonstrated a decrease in the impedance to the current flow with an increasing intensity. A similar observation was recently reported by Wotton and O'Callaghan [17], during the head-only stunning of pigs. These authors concluded that high voltage currents induce a break down in the impedance to current flow, so that the relationship between current and voltage appears to more closely match that expected from Ohm's law. Current intensity did not significantly affect blood loss. Conflicting results have been reported in the literature. In broilers, Veerkamp and De Vries [14] found a decrease in blood loss with increasing stunning voltage, whereas other authors did not demonstrate any effect [1, 5]. In broilers, increasing stunning voltage has been reported to enhance the incidence of carcass defects such as broken bones, red wing tips and petechial hemorrhages (e.g. Ali et al. [1]). With the exception of petechial hemorrhages in the liver of geese, which was the most present after stunning at the highest current intensity, the present data could not demonstrate a clear cut increase in the incidence of appearance defects with increasing stunning intensity.

The present data showed that increasing stunning duration decreases the paleness and enhances the redness of the liver. This effect could be explained by an increased blood retention in the liver, with increasing stunning duration. However, this hypothesis is not confirmed by the subjective assessment of the color of liver lobe tips, nor by the incidence of petechial hemorrhages in the liver, which are assumed to reflect the level of blood vessel damage. In geese, however, stunning for 5 or 13 s led to higher percentages of breast muscles with petechial hemorrhages, than stunning for 2 s. In poultry, breast muscles are the main routes of current flow during water-bath stunning [16]. Therefore, increasing the duration of current flow is expected to enhance the incidence of muscle defects, such as petechial hemorrhages.

Using a 150 mA current for the water-bath stunning of turkeys, Mouchonière et al. [9] showed an improvement in blood loss with increasing current frequency up to 600 Hz. A similar observation was reported by Raj and Johnson [11] in broilers, when comparing a 50 Hz and a 1500 Hz stunning current. In the study by Mouchonière et al. [9], this effect was attributed to a concomitant decrease in the incidence of heart fibrillation. Indeed, 100% of the birds showed irreversible cardiac fibrillation after a 50 Hz stun, whereas none of the birds showed cardiac arrest after a 600 Hz stun. In the present experiment, the current frequency did not affect blood loss. Although the occurrence of cardiac arrest was not recorded, it is likely that the low current intensity (50 mA) used in the present work did not induce heart fibrillation at any of the frequencies used. Therefore, a variation in current frequency did not induce a variation in blood loss. The present data also demonstrated some beneficial effects of high frequency stunning on product downgrading. In ganders, stunning at 1200 Hz consistently improved the color of liver lobe tips and reduced the incidence of petechial hemorrhages in breast muscle. In females, no petechial hemorrhages could be detected in breast muscle after the 1200 Hz stun. The beneficial effect of high frequency stunning on carcass downgrading has already been reported for turkeys [15].

In various poultry species, the incidence of red wing tips has been shown to be highly related to stunning conditions (for a review, see Raj [10]). The present data shows that (i) the incidence of red wing tips may vary from an experiment to another and (ii), it does not seem to depend neither on stunning itself, nor on the conditions of electrical stunning. Other factors, probably related to pre-slaughter handling (catching, transport, shackling, …), may play a prominent role in the apparition of red wing tips in geese.

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