Revista Brasileira de Ciência Avícola
ISSN: 1516-635X
revista@facta.org.br
Fundação APINCO de Ciência e Tecnologia Avícolas
Brasil

Nicolau, JP; Pinto, MF; Ponsano, EHG; Perri, SHV; Garcia Neto, M
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Revista Brasileira de Ciência Avícola, vol. 17, núm. 3, julio-septiembre, 2015, pp. 341-345
Fundação APINCO de Ciência e Tecnologia Avícolas
Campinas, Brasil

Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola
ISSN 1516-635X Jul - Sept 2015 / v.17 / n.3 / 341-346
http://dx.doi.org/10.1590/1516-635x1703341-346

Exposure to Carbonic Gas Enriched Atmosphere or Electrical Water Bath to Stun or Kill Chickens

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■Keywords

Animal welfare, broiler, meat characteristic, slaughter, stunning.

Submitted: June/2014
Approved: January/2015

ABSTRACT

The objective of this study was to compare the effects of two methods (electrical water bath or carbonic gas atmosphere) for stunning or killing broiler chickens prior to bleeding on weight loss due to bleeding and meat traits. A completely randomized design with 2 x 2 factorial arrangement (electrical or gas system x stunning or killing) was applied. The time required for stunning and killing and the birds' behavior were evaluated for the gas exposure method. The birds killed by the electrical method retained more blood than those killed by the exposure to gas and, therefore, presented redder meat. The exposure to 10 to 15% CO_2 atmosphere caused discomfort reactions in 100% of birds, and the intensity of reaction presented a wide variation: 35% for weak reaction, 40% for intermediate reaction, and 25% for strong reaction. The time required to stun or kill the birds by CO_2 exposure varied from 28 to 97 seconds and from 42 to 158 seconds, respectively. It was concluded that the time required to stun or to kill the birds by CO_2 exposure widely varied and caused discomfort reactions; however, meat traits were not influenced by the methods used in this experiment.

INTRODUCTION

Reducing the suffering of animals at slaughter is becoming an important quality attribute for an increasing share of the meat consumer market. Brazilian legislation requires the stunning of animals before bleeding (Brasil, 1998; Brasil, 2000).

In Brazil, as well as in other countries where broiler slaughter is automated, birds are stunned in electrical water bath systems. In this method, the steps prior to electric stunning cause clear discomfort to the birds. During hanging, for instance, there must be maximum contact of the birds' legs with the metal shackle to allow effective application of the electrical current, which means that, depending on broiler size, the feet must be forced into the hooks.

Moreover, the upside down position can cause birds to flap their wings due to fear and discomfort, resulting in distress, suffering, and injuries (Ludtke *et al.*, 2010). Other disadvantages are the difficulty to adjust the equipment to the size of the birds, the occurrence of pre-shocks, inadequate bird positioning, and ineffective stunning.

Some research studies suggest the exposure to controlled atmosphere to replace the electrical systems, either to stun or kill broiler chickens (Raj & Gregory, 1990; Kang & Sams, 1999; Gerritzen *et. al.*, 2000). According to those studies, the exposure of birds to air containing high levels of carbon dioxide caused anesthesia and showed good results. However, carbon dioxide is acidic and irritates mucous membranes during inhalation, causing birds to immediately

stop breathing before the loss of consciousness. Nevertheless, according to Raj & Gregory (1990) and Raj (1998), killing broiler chickens by exposure to controlled atmosphere may minimize their suffering at slaughter.

This study investigated meat traits and weight loss due to bleeding when the birds were stunned or killed by either electrical water bath immersion or by CO_2 exposure. The time required to stun and to kill the broilers, as well as their behavior when submitted to CO_2 exposure were also evaluated.

MATERIAL AND METHODS

Forty 42-day-old male Cobb 500 broilers were divided into four groups of 10 birds each. Birds were individually identified, weighed and transported to the experimental pilot scale abattoir. Each group was submitted to one of the following treatments: 1) electrical stunning (electronarcosis); 2) electrical killing (electrocution); 3) CO_2 stunning, or 4) CO_2 killing.

The experiment followed a completely randomized design in a 2 x 2 factorial arrangement (electrical or gas system x stunning or killing) with 10 replicates per treatment. Parameters were evaluated per individual bird, and therefore, each bird was considered as an experimental unit for the analysis of variance (Perret, 2012). The slaughter procedures were performed according to the Brazilian legislation (Brasil, 1998).

Electrical method

A pilot scale electrical equipment, consisting of overhead rails with metal shackles to hang the birds and an electrified water bath, with capacity to apply electric current to one bird at a time, was used. The electrical current parameters were fixed at 240 V AC, 60 Hz, and 120 mA. Therefore, the only parameter that was changed in order to cause electronarcosis or electrocution was the exposure time of the bird to electric current. The electrical stunning was performed by immersing the bird's head for 3 seconds in electrified water to produce effective unconsciousness. Birds were considered stunned when both nictitating membrane reflex and rhythmic breathing were absent. Rhythmic breathing was indicated by contraction of the abdominal muscles near the cloaca (Ludtke *et al.*, 2010).

In order to kill the broilers by the electrical method, the bird's head was immersed in electrified water for 8 to 10 seconds, until death, as confirmed by the observation of the complete respiratory arrest.

CO2 exposure method

The birds were exposed to CO_2 enriched atmosphere in a pilot scale stainless steel experimental chamber with acrylic ceiling, in order to allow the observation of birds' behavior, attached to a CO_2 gas cylinder. CO_2 concentration was monitored by a Scenty GDZ 203 HTK Hamburg GMBH gas analysis system, equipped with a 760 GMF 0 to 100% CO_2 sensor inside the chamber. The Brazilian legislation determines a minimum CO_2 concentration of 30% for the stunning of chickens (Brasil, 2000). However, according to Bitencourt (2011), birds suddenly submitted to this CO_2 level may show agitation and/or convulsive reactions. Therefore, this experiment used an initial 10% CO_2 concentration, which was gradually increased until the bird was completely stunned, at approximately 13% CO_2. Birds were individually placed inside the chamber. Prior to each new stunning procedure, the gas concentration was set back to 10%. The broilers were considered stunned when they fell and did not present any rhythmic breathing movement or nictitating membrane reflex.

The same procedures were carried out to kill the birds. In this case, however, the bird was maintained in the chamber until it died, as confirmed by complete respiratory arrest, which happened at a CO_2 concentration of approximately 15%.

Behavior Evaluation of the Birds Exposed to CO_2

During the exposure to the CO_2 atmosphere, the behavior of the birds before they fell was classified as "no reaction", when the bird presented only tachypnea; "weak reaction", when the bird gasped and/or shook its head, "intermediate reaction", when the bird presented weak and intermittent wing flapping; and "strong reaction", when the bird presented continuous and strong wing flapping.

Weight Loss after Bleeding

All birds were individually weighed, bled immediately after stunning or killing by either electrical or gas treatment, and then weighed again to determine weight loss due to bleeding, expressed as a percentage of live weight.

Meat pH

Breast and thigh meat pH was determined 24 hours after slaughter using a pHmeter (Mettler Toledo Model 1120-X) with a penetrating probe.

Meat Color

Breast and thigh meat color was evaluated after the skin was removed and in triplicate, using Hunterlab Miniscan XE Plus with D65 illuminant and 10º observation angle. Color was expressed according to the *CIELab* color system, which attributes L* (lightness), ranging from zero (absolute black) to 100 (absolute white); a*, ranging from green (negative values) to red (positive values); and b*, ranging from blue (negative values) to yellow (positive value) (Minolta, 2007).

The equipment was positioned on the dorsal surface of the breast fillet and on the lateral surface of the thighs, avoiding hemorrhagic petechiae, discolored spots, and any other color interference.

Statistical Analysis

The results were submitted to analysis of variance and means were compared by Duncan's test at 5%significance level. Pearson's linear correlation coefficient among variables was determined (Zar, 2009). Statistical analyses were performed using the Statistical Analysis System (SAS, 2008).

RESULTS AND DISCUSSION

Broilers submitted to gas method presented lower and higher meat redness and lightness values, respectively, compared with those of broilers submitted to the electrical method ($p < 0.05$), probably due to the smaller amount of residual blood in the muscles, as shown by the significantly lower weight loss due to bleeding of the birds submitted to the electrical method (Table 1).

The birds killed by the electrical method presented higher thigh meat pH compared with those in the other treatments (Table 2). This may be explained by the longer time of exposure of the birds to electricity, causing muscle contraction and depletion of muscle energy reserves (Judge, 1989). As muscle glycogen stores are depleted, less lactic acid is produced, and consequently lower muscle pH decrease after slaughter.

Weight loss due to bleeding was not different between broilers stunned and killed by either of the methods applied (electrical and gas). However, when both methods are compared, electrically killed broilers lost significantly less weight after bleeding than those

Table 1 – Weight loss due to bleeding and breast and thigh meat traits of broilers submitted to electrical or gas stunning or killing.

Factors	Parameters								
	Weight loss due to bleeding (%)	pH		L*[1]		a*[2]		b*[3]	
		Breast	Thigh	Breast	Thigh	Breast	Thigh	Breast	Thigh
Methods (M)									
Electrical	2.65[b]	6.06	6.49	61.99[b]	61.96	5.51[a]	6.83	14.95	13.21
Gas	3.56[a]	6.10	6.46	64.69[a]	63.48	4.47[b]	5.58	15.15	15.61
Procedures (P)									
Stunning	3.14	6.04	6.38[b]	62.75	62.06	5.06	5.59	15.78	13.45
Killing	3.00	6.13	6.59[a]	63.93	63.38	4.92	6.82	14.32	15.38
P value									
M	0.0002	0.4907	0.6131	0.0266	0.2835	0.0131	0.2199	0.8413	0.4097
P	0.9269	0.1052	0.0009	0.3207	0.3508	0.7406	0.2239	0.1487	0.5057
M x P	0.0111	0.5747	0.0216	0.0728	0.1224	0.0016	0.9849	0.4259	0.2267
CV (%)[4]	21.62	2.80	2.54	5.84	7.07	25.18	50.95	20.79	63.04

[a-c] Means followed by different letters in the column are significantly different by Duncan's test ($p<0.05$). 1 = lightness; 2 = redness; 3 = yellowness; 4 = coefficient of variation

killed by gas exposure. This may be explained by the application of 120 mA electrical current, which can cause the rupture of intramuscular blood vessels and blood retention in muscle tissue (Gregory & Austin, 1992; Lambooij *et. al*., 1999).

Table 2 – Deployment of the interactions among treatments for weight loss due to bleeding, thigh meat pH, and breast meat redness.

Methods	Procedures	Parameters		
		Weight loss due to bleeding (%)	Thigh pH	*a* (breast redness)
Electric	Killing	2.41^{c}	6.66^{a}	6.12^{a}
	Stunning	2.97^{bc}	6.33^{c}	4.90^{b}
Gas	Killing	3.89^{a}	6.50^{b}	3.73^{c}
	Stunning	3.30^{ab}	6.43^{bc}	5.21^{ab}

$^{a-c}$ Means followed by different letters in the same column are significantly different by Duncan's test ($p<0.05$).

The influence of the amount of blood drained from the carcasses on meat redness is confirmed by Pearson's correlation results, shown in Tables 3 and 4. There was a negative correlation between these parameters, indicating that the greater the weight loss caused due to bleeding, the lower was the *a* value. A higher and more significant correlation was found for thigh meat, which redness is more intense due to a higher concentration of myoglobin and to a more developed vascular system compared with breast muscles (Varnam & Sutherland, 1995). A significant correlation between breast and thigh meat pH and *b* values was also observed. However, considering that the breast meat pH values were not different between treatments, it is not possible to associate these results with the method of stunning or killing.

Table 3 – Pearson's correlation coefficients for breast meat parameters

	pH	L*[1]	*a**[2]	b*[3]
Weight loss due to bleeding	0.2259	0.0872	-0.4580	-0.1622
p-value	0.3673	0.7307	0.0560	0.5201
pH		-0.1053	-0.1986	-0.4715
p-value		0.6775	0.4294	0.0482
L*			-0.4086	0.0626
p-value			0.0923	0.8050
*a**				0.2514
p-value				0.3142

[1] = lightness; [2] = redness; [3] = yellowness.

Table 4 – Pearson's correlation coefficient for thigh meat parameters

	pH	*L*[1]	*a*[2]	*b*[3]
Weight loss due to bleeding	-0.2767	0.1072	-0.6809	-0.0926
p-value	0.2662	0.6721	0.0019	0.7147
pH		-0.1226	0.4494	-0.5230
p-value		0.6280	0.0613	0.0259
L			-0.2865	0.2414
p-value			0.2490	0.3346
a				0.1037
p-value				0.6823

[1] = lightness; [2] = redness; [3] = yellowness.

According to Grandin (2010), there has been much controversy about the effect of different gases on bird discomfort during the induction of insensibility. This is why, in the present study, the initial CO_2 concentration used was 10%, and then was gradually increased after the birds were placed into the chamber. All birds reacted when exposed to CO_2, both during the killing and the stunning procedures: 35% presented weak reaction, 40% intermediate reaction, and 25% strong reaction (Figure 1).

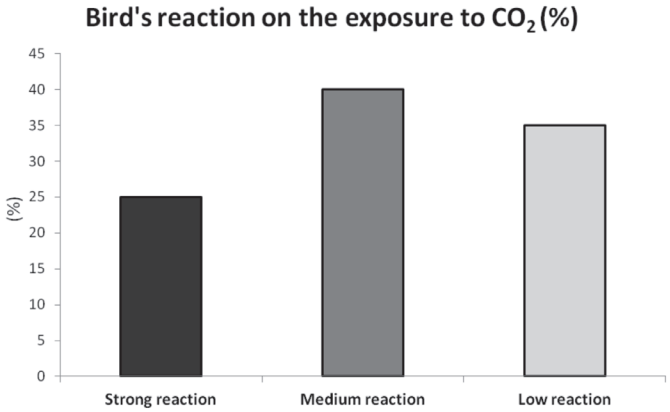

Figure 1 – Birds' reaction, in percentage, on the exposure to CO_2.

The time required to stun and to kill the birds by the gas exposure method presented a wide variation, ranging from 28 to 97 seconds for stunning and from 42 to 158 seconds for killing. Under experimental conditions, birds' reactions to the gas may be different when compared with those observed in processing plants. Specific gas concentrations that can be easily maintained at laboratory scale may be difficult to maintain in commercial facilities (Grandin, 2010). Therefore, in practice, the adoption of gas stunning method presents some difficulties.

The results of the present study demonstrated that the gas exposure method did not prevent bird discomfort and resulted in a wide variation in individual broilers' responses, precluding the standardization of the process parameters. Therefore, considering the high costs of installing and operating the method of gas exposure and the fact that most broiler processing plants operate with electrical equipment, it is suggested that investing in the optimization and standardization of the electrical equipment parameters is more feasible to reduce broiler suffering then implementing other stunning methods. Furthermore, electrical current parameters may be set to kill he birds, which would bring undeniable welfare benefits, reduce the occurrence of conscious birds at bleeding and the possibility of birds get drowned in water baths in the case of possible interruptions in the slaughter line.

CONCLUSIONS

It was demonstrated that the exposure of broilers to 10 to 15% CO_2 atmosphere is an inefficient technological alternative to reduce suffering. In addition, it is an unfeasible industrial application due to the wide variation in the time required to stun or to kill the birds. Killing poultry both by the methods of electrical water bath and exposure to CO_2, followed by immediate bleeding, did not cause any meat trait changes that may adversely affect product acceptance by the consumers.

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