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Effect of Different CO_2 Concentrations on the Stunning Effect of Pigs and Selected Quality Traits of Their Meat – a Short Report

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Key words: pharmacological stunning of fatteners, quality of meat

The aim of the study was to analyse the effect of CO_2 concentration in pharmacological stunning method of pigs on selected quality traits of meat. Investigations were carried out on 200 fatteners of mass population. Half the animals (n=100) were stunned with 92% and the other 100 fatteners were stunned with 88% CO_2. The stunning effectiveness was evaluated by observing animals' response to CO_2 concentration. In the group of the fatteners stunned with 92% CO_2 all animals were stunned correctly, whereas in the group of the fatteners stunned with a lower concentration of CO_2 (88%), the percentage of ineffectively stunned animals reached 17%. A statistically significant ($p \leq 0.01$) influence of carbon dioxide concentration in the pharmacological stunning method was noticed on pH_{24}, lightness of meat – L* ($p \leq 0.05$) and b* value. A higher frequency of carcasses with PSE and DFD was observed among the fatteners stunned with 92% CO_2 (respectively 16% and 7% *vs*. 9% and 1% reported for animals stunned with 88% CO_2).

INTRODUCTION

The good quality of meat is determined by genetic and environmental factors. Amongst the environmental factors, a significant influence on the quantitative and qualitative losses of meat is ascribed to slaughter operations, the stunning and bleeding in particular.

For several years a growing interest has been observed in pigs stunning with carbon dioxide. Stunning with this method corresponds to, a greater extent, to the requirements for animal and consumer protection than mechanical or electrical stunning [Christensen, 2008]. In the meat of pharmacologically-stunned pigs, sheep and lambs, lesser blood splashes were stated, and the pork was characterised by smaller losses of weight due to drip [Gregory, 2005; Christensen, 2008]. The response of pigs to carbon dioxide is dependent on its concentration. In accordance with EU Council Directive 93/119/CE [1993], the minimum concentration of carbon dioxide in pigs stunning may not be lower than 70%, although the faster loss of consciousness of animals is observed at 100% CO_2. Many slaughterhouses have applied pigs stunning using 90% concentration of CO_2 [Gregory, 2008].

As reported by Bórnez *et al.* [2009], the concentration of carbon dioxide in animal stunning contributes not only to the loss of their consciousness, but may be the cause of certain physiological responses, consequently affecting the quality of meat.

In view of the above, the aim of this study was to analyse the effect of CO_2 concentration in the pharmacological method of pigs stunning on selected quality traits of their meat.

MATERIAL AND METHODS

The studies were conducted in May 2008 on 200 porkers of mass population. The fatteners were slaughtered in accordance with the procedure adopted at the Meat Plant Łmeat – Łuków S.A. Half the animals (n=100) were pharmacological stunned with 92% concentration of carbon dioxide, while the other 100 fatteners were stunned with 88% concentration of this gas. The stunning of animals proceeded in a stunning chamber of Butina Combi 44 type. It operates based on the principle of putting pigs in a vertical chamber immersed in a trough, with a mechanical transport of cabins and automatic dispensing of gas from a tank of liquid CO_2. The whole stunning cycle lasted about 1 minute and 6 seconds, while the stunning itself lasted 16 seconds.

After the animals have left the gas chamber, the effectiveness of the stunning method was evaluated by observing their response to the applied concentration of CO_2 (by loss of consciousness) [Wojtaszek, 2006]. The animals were bled in a hanging position.

The analysed fatteners were characterised by high mean lean meat content (estimated at the UltraFom 300 apparatus), *i.e.* 54.94±3.84 % with a high range of variability of hot carcass weight – 82.24±8.07 kg. The evaluation of the quality of meat was performed after slaughter on the *Longissimus dorsi* muscle (in *Longissimus lumborum*-LL section) on

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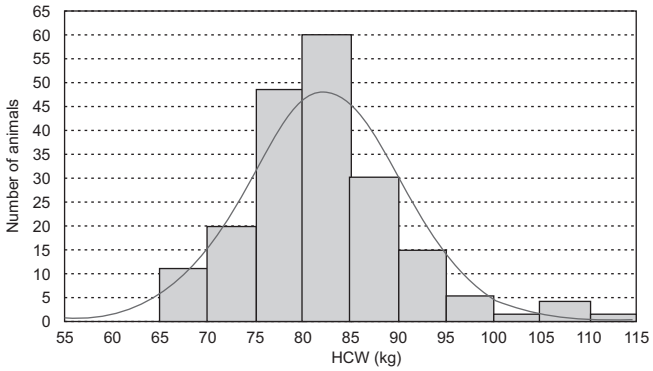

FIGURE 1. Distribution of hot carcass weight (n=200).

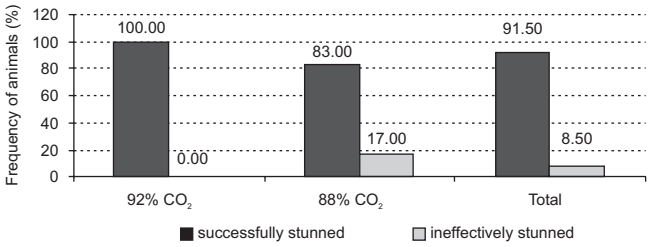

FIGURE 2. The frequency of successfully and ineffectively stunned animals.

the basis of the following parameters: pH value measured at 45 min and 24 h *post mortem*, using Hanna Instruments HI 9025 pH meter with FC 200 electrode; and the lightness of the muscle tissue determined 24 h after slaughter using a Minolta CR 310 apparatus.

In order to separate meat quality classes, the study material was classified on the basis of the following extreme values obtained for pH_1 and pH_{24} [Koćwin-Podsiadła *et al.,* 1998]:

- Normal – pH_1 ≥6.0 and pH_{24} 5.51–5.99
- PSE – pH_1 <6.0 and pH_{24} 5.51–5.70
- Acidic meat – pH_1 ≥6.0 and pH_{24} ≤ 5.50
- DFD – pH_1 ≥6.0 and pH_{24} ≥6.0.

The results obtained were elaborated statistically using Statistica 6.0 program. The effect of the effectiveness of animals stunning on the analysed quality traits of meat was determined using a one-way analysis of variance in the non-orthogonal scheme according to the linear model:

$$y_i = \mu + a_i + e_{ij}$$

where: μ– total mean, a_i – effect of the analysed factor, e_{ij} – random error.

Moreover, using a two-way analysis of variance, the influence of CO_2 concentration in the pharmacological stunning method and hot carcass weight on meat quality traits was analysed according to the linear model:

$$y_i = \mu + a_i + b_j + ab_{ij} + e_{ij}$$

where: μ – total mean, a_i – effect of CO_2 concentration (92% and 88%), b_j – effect of hot carcass weight (I <80 kg, II 80.1–85 kg, III >85 kg – class set on the basis of distribution – Figure 1), ab_{ij} – interaction; e_{ij} – random error.

The significance of differences between mean values was verified using the NIR test [Statistica 6.0 – StatSoft, Tulsa, USA].

RESULTS AND DISCUSSION

Immediately after stunning, analyses were conducted for the effectiveness of the applied concentration of carbon dioxide in the pharmacological method of stunning which consisted in observations of the animals response to stunning (loss of consciousness). Symptoms of effective stunning with a mixture of gases include among other things: widened pupils, atrophy of corneal reflexes, loss of rhythmic breathing, short-term choking or gasping for breathe, a lack of response to nose pricking with a subcutaneous needle, and complete atony of the stunned carcass without pulse. In turn, symptoms of the ineffective stunning include: narrowed pupils, rhythmical breathing, attempts of raising head, vocalization during stunning and/or attacks, corneal reflexes, and response to pain stimuli [Wojtaszek, 2006; Nowak *et al*., 2007 after Blackmore & Newhook, 1981; after Gregory *et al*., 1987; after Velarde *et al*., 2000; after Holst, 2001].

In the population of fatteners stunned with the pharmacological method using 92% concentration of CO_2, 100% of the animals were stunned successfully (Figure 2). In turn, in the group of fatteners stunned with a lower concentration of carbon dioxide (88%), 17% of the animals did not manifest complete loss of consciousness after stunning.

The one-way analysis of variance demonstrated that the animals unsuccessfully stunned with 88% CO_2 differed significantly ($p \leq 0.05$) from the other fatteners only in respect of hot carcass weight which was lower by 3.17 kg than that of the successfully stunned animals (Table 1).

The observed tendency enabled analysing the effect of the applied CO_2 concentration in the pharmacological method of stunning on the assayed attributes of meat quality and hot carcass weight (Table 2).

The two-way analysis of variance demonstrated a statistically-confirmed significant ($p \leq 0.01$) correlation between the first experimental factor, *i.e.* the concentration of carbon dioxide applied in the pharmacological method of animals stunning and the value of pH_{24}, lightness of meat L* ($p \leq 0.05$) and the chromaticity coordinate b* corresponding to the yellow colour (Table 2). In contrast, the statistical analysis did not

TABLE 1. Influence of stunning effectiveness on the analysed meat quality traits in the fatteners stunned with 88% CO_2 (n=100).

Specification	Animals stunned successfully (n=83)	Animal stunned ineffectively (n=17)	Femp
Hot carcass weight (kg)	82.67^{b}±5.85	79.50^{a}±5.10	4.21^{X}
pH_{45}	6.27±0.22	6.27±0.23	0.00NS
pH_{24}	5.63±0.14	5.62±0.14	0.001NS
Lightness of meat L*	54.86±2.85	54.96±3.29	0.01 NS
a*	15.45±1.02	15.52±1.02	0.06 NS
b*	3.80±0.53	3.85±0.68	0.09 NS

Explanations: The data shown in the table are arithmetic means and standard deviations. NS – differences insignificant; $^{X}p \leq 0.05$.

TABLE 2. Effect of CO_2 concentration and hot carcass weight on the analysed meat quality traits.

Traits	Concentration of CO_2 (%)		Signific.	Hot carcass weight (HCW) (kg)			Signific.	Total	Interact% CO_2 ×HCW
	92%	88%		≤80	80.1–85	>85			
No of animals	100	100		77	66	57		200	
Hot carcass weight (kg)	82.35±9.84	82.14±5.83	0.03NS	74.91^{A}±3.54	82.51^{B}±1.5	91.85^{C}±6.61	255.61^{XX}	82.24±8.07	2.86NS
pH_{45}	6.24±0.29	6.28±0.23	0.35NS	6.23±0.26	6.30±0.23	6.20±0.27	2.14NS	6.26±0.25	0.02NS
pH_{24}	5.77^{B}±0.15	5.62^{A}±0.14	55.97^{XX}	5.70±0.14	5.70±0.17	5.71±0.17	1.26NS	5.70±0.16	2.45NS
Lightness of meat L*	53.88^{a}±2.68	54.98^{b}±2.91	10.15^{X}	54.58±2.95	54.09±2.74	54.69±2.81	2.23NS	54.38±2.84	1.41NS
a*	15.37±0.84	15.46±1.02	0.14NS	15.43±0.99	15.37±0.91	15.50±0.84	0.26NS	15.41±0.93	0.57NS
b*	3.45^{A}±0.51	3.81^{B}±0.55	25.78^{XX}	3.67±0.54	3.63±0.56	3.54±0.62	0.76NS	3.63±0.55	2.21NS

Explanations: The data shown in the table are arithmetic means and standard deviations. NS – differences insignificant; $^{XX}p\leq0.01$; $^{X}p\leq0.05$.

confirm the effect of the second experimental factor, *i.e.* hot carcass weight, on quality attributes of pork. No correlation was confirmed either between the two experimental factors (CO_2 concentration x hot carcass weight).

Analyses conducted in this study demonstrated that the fatteners stunned with the lower concentration of CO2 (88%) were characterised by higher acidification of meat tissue 24 h *post mortem* and by lighter colour of meat as compared to the animals stunned with 92% CO_2 (Table 2). It is worthy of notice, however, that the analysed fatteners were similar in terms of hot carcass weight, yet displayed high variability of that trait expressed by standard deviation from the mean (Table 2).

Thus, the results obtained confirm the greater impact of CO_2 applied in the pharmacological method of stunning than of the hot carcass weight on meat quality of the fatteners.

As reported by Meller [1992], Candek-Potokar *et al.* [1998], and Koćwin-Podsiadła *et al*. [2002], no significant effect of weight at slaughter on the quality of meat obtained has been demonstrated in the populations of pigs free of the major genes RYR 1 and RN^{-}.

A number of studies have pointed to a lack of a statistically-confirmed correlation between weight at slaughter and pH_{45} [Leach *et al.*, 1996; Sutton *et al.*, 1997; Sonesson *et al.*, 1998], pH_{24} [Sutton *et al.*, 1997; Meller, 1992; Huff-Lonergan *et al.*, 2002; Koćwin-Podsiadła *et al.*, 2002] and lightness of meat colour [Leach *et al.*, 1996; Candek-Potokar *et al.*, 1998; Sieczkowska *et al.*, 2001; Koćwin-Podsiadła *et al.*, 2002].

The frequency of faulty meat of fatteners as affected by the method of stunning using various concentrations of CO_2 was presented in Figure 3.

A higher frequency of faulty PSE and DFD meat was observed in the group of fatteners stunned with 92% carbon dioxide (respectively 16% and 7% *vs.* 9% and 1% for animals stunned with 88% CO_2). In turn, the occurrence of acidic meat was reported only in the fatteners stunned with 88% CO_2, 17% were not successfully stunned (Figure 2). A comparison of the frequency of faulty meat in groups of animals differing in the effectiveness of stunning confirmed as substantially higher frequency of carcasses with acidic meat amongst the ineffectively stunned animals (23.53% *vs*. 15.66%) (Figure 4).

A research conducted with pigs in Germany demonstrated that the application of a gas mixture of 90% CO_2 in the pharmacological method of stunning yielded better results than 80% CO_2 [Gregory, 2008]. In the first case, the frequency of PSE meat was significantly lower.

The higher frequency of PSE meat (16%) noted in the fatteners stunned with 92% CO_2 is most likely to be due to animals' response to the higher concentration of gas, or from the burdening of the analysed population of pigs with stress susceptibility gene, because the PSE syndrome occurs in the stress-susceptible animals affected by either physical or psychical stimuli shortly before slaughter (including among other stunning). In the animals with genetic predisposition for myopathy a rapid course of glycogenolysis is initiated during slaughter, which leads to the accumulation of lactic acid in

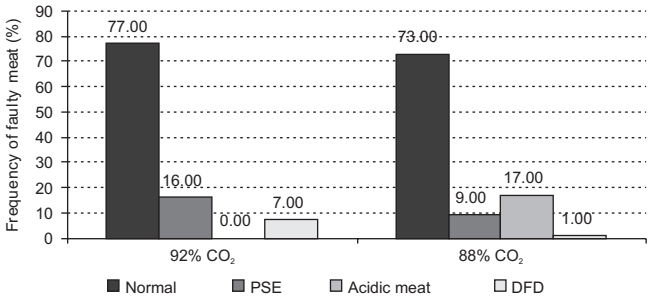

FIGURE 3. The frequency of faulty meat of fatteners stunned with the pharmacological method using different concentrations of CO_2.

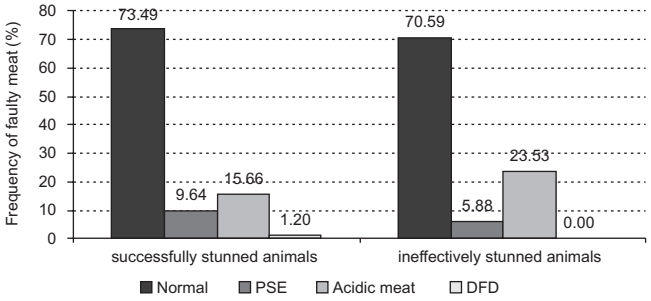

FIGURE 4. The frequency of faulty meat of fatteners differing in the effectiveness of stunning with 88% CO_2.

muscles and thus to a rapid decline in pH value [Koćwin–Podsiadła, 1998].

Velarde *et al.* [2007] in their comparative studies on the aversive response of livestock with a negative halothane reaction and of heterozygotes with the positive reaction stunned with CO_2, observed that when the stunning chamber was filled with 90% carbon dioxide the pigs needed statistically significantly more time to enter the stunning gondola than these stunned with 70% CO_2. In the case of stunning with 90% CO_2, the number of animals trying to escape was twofold higher (77%) as compared to the stunning with CO_2 used in 70% concentration (36%). The animals resistant to stress (NN) were undertaking fewer attempts of escaping than the heterozygotic pigs (Nn). The aversion of pigs to 90% CO_2 was greater than to 70% CO_2, still in the environment with the higher concentration of CO_2 the animals were observed to lose consciousness faster than in the environments with the lower concentrations of carbon dioxide.

CONCLUSIONS

In summary of the results achieved in this study on the effect of CO_2 concentration in the pharmacological method of pigs stunning on selected quality attributes of their meat, it may be concluded that the applied method of pigs stunning, and to be more precise – the concentration of CO_2 applied during stunning, has a significant impact on changes in the post-slaughter physicochemical and functional properties of pork. The results obtained prompt us to conduct in-depth analysis on the material with known genotype, as well as equal hot carcass weight and meatiness, for these factors greatly affect the response of pigs to CO_2.

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