S5P17.WP

USE OF NITROUS OXIDE FOR PIG STUNNING. PRELIMINARY RESULTS

G. Monin, A. TALMANT, P. VERNIN and C. VEILLAS[1]

Station de Recherches sur la Viande, INRA, 63122 St Genès, Champanelle
1 Société Air Liquide, Centre de Recherches Claude Delorme, 78350 Jouy-en-Josas, France

INTRODUCTION

Stunning of pigs for slaughter is performed most frequently using electrical current or carbon dioxide/air mixtures. From the humane point of view, the use of CO_2 is still controversial. The animals show frequently excitation and increased motor activity when exposed to CO_2. These signs can be interpreted as conscious flight reactions which suggests that the pigs could experience some unease at least at the beginning of gas-exposure (Troeger and Wolsterdorf, 1991). On the other hand, Forslid (1991) reported from EEG recordings that the increased motor activity is unconscious. Gregory (1992) concluded that "clearly this issue still needs investigating as there is no consensus".

CO_2 stunning was reported to give less bone fractures and blood splashing than electrical stunning (Larsen, 1983). Concerning meat quality, its effects have been controversial. CO_2 stunning causes acidification of the organism, due to lactic acid production resulting from muscle activity and hypoxia, or/and to a direct effect of CO_2 (the latter is the anhydride of carbonic acid). This acidification could contribute to lower the post-mortem muscle pH and so favour the occurrence of PSE meat. An alternative gas for anaesthesia of slaughter pigs could be the nitrous oxide N_2O (laughing gas), which is frequently used in surgical anaesthesia in humans and animals. This gas is authorized in the food industry. Its density is close to that of CO_2, and so it could be used with similar equipments. Troeger and Wolsterdorf (1991) found that unconsciousness could not be achieved using N_2O/CO_2/air mixtures, even after gas-exposure for three minutes. However, Delpuech (1976) obtained full anaesthesia in chicken and piglets with N_2O/air mixtures at 70 to 80% N_2O.

The aim of the present study was to investigate the efficiency of N_2O as a stunning agent and its effects on meat quality, particularly in comparison with CO_2.

MATERIALS AND METHODS

Animals

The pigs were Large White or Large White x French Landrace, weighing 95 to 105kg. They were bought from a pig deal one week before experiments. All the pigs in one given experiment came from the same farm.

Stunning equipment

Electrical stunning was performed using a manual Etim apparatus (Etim Company, France). The current of 300V and around 0.5A was delivered for one to two seconds.

Gas stunning was performed in a closed cage of approximately 400dm^3 volume. The animal was introduced into the cage, then pure CO_2 or N_2O was blowen till a residual oxygen concentration of 5% in case of CO_2 and 4% in case of N_2O, corresponding approximately to concentrations of 75% CO_2 and 80% N_2O respectively. These concentrations had been determined in preliminary trials where concentrations of 75 to 85% were tried. Oxygen was continuously measured witha Beckman 777 apparatus. The animal reactions were observed throughout exposure to stunning gases.

Experiment 1

Six Large White pigs were stunned using N_2O, then again a week later using CO_2. As soon as unconsciousness was judged to be achieved, the animals were pulled out of the cage. Blood was obtained immediate by *vena cava* puncture and analyzed for pH, bicarbonate, pCO_2 and pO_2 with a Radiometer BMS2 blood gas analyzer. The animals were allowed to recover in air. They were considered to have recovered consciousness as soon as they manifested perception of shocks from an electric rod of a type usually used for pig handling. Times to obtain the final gas concentrations, to achieve apparent anaesthesia and to get recovery were registered.

Experiment 2

Twenty LW pigs were used. Ten of them were stunned by electric current and the 10 others by N_2O. The latter were kept in the cage of two minutes after the beginning of exposure to stunning gas. All the pigs were exsanguinated and the carcasses were dressed according to commercial procedures. At one hour after slaughter, a sample was taken from the *gluteus superficialis* and put in liquid nitrogen for later measurement of pH (pH_1), lactic acid and ATP. The day after slaughter, the left ham was scored for meat quality (0=PSE to 4=good quality), then a sample of *biceps femoris* was taken for determination of ultimate ph (pH_2), water holding capacity (press method of Goutefongea, 1966) and reflectance at 630nm. The hams from six pigs of each group were processed into cured cooked ham.

Frozen samples of *gluteus superficialis* were ground with liquid nitrogen in a Waring blender. Two grams of frozen powder were homogenized in 18ml of 0.005M iodoacetate and pH was measured on the homogenate. Five grams of powder were homogenized in 0.6M perchloric acid for determination of ATP and lactic acid by classical enzymatic techniques (Bergmeyer, 1974).

Experiments 3 and 4

Twenty LW x Landrace pigs were used in each of these experiments. Ten of them were stunned by CO_2 and then 10 others by N_2O. All the animals were kept in the cage for two minutes after the beginning of exposure to stunning gas. Then they were exsanguinated and measurements of meat quality were performed in the same way as in experiment 2. Times to obtain the final gas concentrations and to achieve apparent anaesthesia were registered in experiment 3.

RESULTS and DISCUSSION

Anaesthesia

Time to achieve apparent unconsciousness was found to be slightly shorter with N_2O in experiment 1, but the contrary was observed in experiment 3 (Table 1). This time was much longer than that reported by Troeger and Wolsterdorf (1991) for CO_2 stunning, i.e., 30 to 40 seconds. This difference was undoubtedly due to the differences between both studies in stunning equipment. In the experiments of Troeger and Wolsterdorf, pigs were lowered in a box filled with the CO_2/air mixture, so the gas concentrations were kept constant throughout gas-exposure. In our conditions, the final gas concentrations were reached only after 40 to 55 seconds. Times for recovery of apparent consciousness were similar with both gases. Muscular activity during bleeding was more marked in N_2O stunned pigs. None of the CO_2 stunned pigs showed activity during bleeding, while five of the 10 N_2O pigs struggled more or less.

There was a striking difference in blood acid-base parameters between CO_2 and N_2O treatments. With N_2O, the values of pH, pCO_2 and HCO_3- were kept almost normal after around 80 seconds of gas-exposure. By contrast, a marked respiratory acidosis developed in CO_2 stunned pigs. The values observed for blood acid-base parameters after CO_2 stunning agreed with the observations by Forslid and Augustinsson (1988). It appears clearly that acidosis observed in CO_2 stunning was due almost completely to a direct effect of CO_2 itself, and not to the hypoxia induced by lowering oxygen concentration. Also, these observations suggest that the physiological stress is less with N_2O than with CO_2 stunning. This is supported by the trend to a lower lactic acid level in the musculature of N_2O stunned pigs (Table 2).

Meat quality

Post-mortem pH fall was faster in electrically stunned pigs than in N_2O stunned pigs (Table 2). However, no significant difference was found for the other meat quality criteria between both stunning techniques.

In experiment 3, post-mortem glycolysis was slower and meat quality was better in N_2O stunned pigs than in CO_2 stunned pigs. No significant difference was found between both treatments in experiment 4, however there was again a slight trend to a better meat quality in N_2O stunned pigs.

CONCLUSION

The results of the present study show that stunning of slaughter pigs can be achieved using the laughing gas N_2O. The physiological stress seems to be lower with N_2O stunning than with CO_2 stunning. This could explain the slower post-mortem glycolysis observed after N2O stunning in experiment 3 (similar trend in experiment 4). The indications that meat quality would be better with N_2O are encouraging and deserve further investigation. However, the present experiments were insufficient to allow conclusions on the very important issue of welfare. Indeed, the conditions of gas-exposure were far from the practical abattoir conditions, since the time needed to reach the high gas concentrations required for stunning was unusually long. Comparison of the effects of CO_2 and N_2O on animal welfare and meat quality in conditions close to those prevailing in abattoirs is needed.

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Table 1. Effects of stunning gas on anaesthesia parameters and acid-base parameters.

	Experiment 1 CO_2 (n=6)	Experiment 1 N_2O (n=6)	Experiment 3 CO_2 (n=6)	Experiment 3 N_2O (n=6)
Time for final gas concentration (s) (1)	52±6	52±6	44±7	48±10
Anaesthesia (s) (2)	102±20[a]	81±12[b]	76±20[a]	95±12[b]
Recovery (s) (3)	207±20	191±23		
Blood pH	6.72 ± 0.10[a]	7.36 ± 0.07[b]		
Blood pCO_2 (kPa)	21.6 ± 7.1[a]	4.7 ± 0.9[b]		
Blood HCO_3^- (meq/l)	19± 3	19± 2		
Blood pO_2 (kPa)	3.7± 0.7	3.2± 2.1		

1 Time to reach an oxygen concentration of 5% in the case of CO_2 and 4% in the case of N_2O.
2 Time to reach apparent anaesthesia.
3 Time to reach apparent consciousness recovery.

Table 2. Effect of different stunning techniques on meat quality.

Traits of meat quality [1,2]	Experiment 2 Elec.	Experiment 2 N_2O	Experiment 3 CO_2	Experiment 3 N_2O	Experiment 4 CO_2	Experiment 4 N_2O
ATP, µmol/g	1.8± 0.7[a]	3.4± 0.7[b]	3.5± 0.7	4.0± 1.0	2.1± 1.2	2.5± 1.9
Lactic acid, µmol/g	52 ± 8[a]	30 ± 9[b]	40 ± 12[a]	29 ± 9[b]	49 ± 15	43 ± 26
pH_1	6.1± 0.2[a]	6.5± 0.3[b]	6.5± 0.3	6.6± 0.7	6.2± 0.3	6.4± 0.5
pH_2	5.8± 0.1	5.7± 0.2	5.5± 0.2	5.7± 0.2	5.6± 0.5	5.6± 0.5
Quality score	1.7± 0.8	2.2± 0.8	1.5± 0.7[a]	2.3± 0.8[b]	-	-
WHC, %	25 ± 6	23 ± 3	26 ± 4[a]	22 ± 4[b]	27 ± 4	26 ± 4
Reflectance, %	73 ± 10	68 ± 16	91 ± 6	80 ± 18	86 ± 5	84 ± 6
Cooking yield, %	69.5± 2.9	69.1± 3.5	68.5± 2.3[a]	68.5± 2.6[b]	66.4± 3.9	67.0± 1.6

1 ATP, lactic acid and pH_1 in *gluteus superficialis*; the other traits in *biceps femoris*.
2 n=10 in all experimental groups except for cooking yield of ham (n=6).