DEVELOPMENT OF PSE - RAPID POST MORTEM GLYCOLYSIS OR LOW pH IN THE MUSCLES AT SLAUGHTER?

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INTRODUCTION

The development of PSE is usually attributed to an increased glycolysis rate post mortem (pm) (Wismer-Pedersen, 1959; Wismer-Pedersen & Briskey, 1961). If the pigs are stressed just before slaughter there may be an increased metabolic activity in the muscles. This continues after slaughter and gives the low pH at 45 minutes pm which caracterize carcasses with PSE (Löwe et al., 1977). The high metabolic rate in the mucles before slaughter may give an accumulation of lactate and a low pH in the muscles before post mortem glycolysis starts. It is thus not clear if the rate of the pH decrease is higher in PSE than in normal carcasses.

In pig loin muscle (M. longissimus dorsi), the pH is approximately 7 at rest, and the value varies between 6.9 and 7.3 (Tarrant et al., 1972; Bendall, 1973; Löwe et al., 1977). With exercise the pH can drop to values about 6.10 (Lindberg et al., 1973; Löwe et al., 1977). In human M. quadriceps femoris the pH level at rest is also about 7 (Hermanssen & Osnes, 1972; Sahlin et al., 1975). In this muscle the pH drops to levels beteen 6.4 and 6.8 during exercise (Sahlin et al., 1975; Sahlin & Henriksson, 1984; Sahlin, 1986). The results from some references are summarised in Table 1.

In a normal carcass the pH in the loin muscle drops to values between 5.3 and 5.8 at 24 hours pm (Wismer-Pedersen, 1959; Briskey & Wismer-Pedersen, 1961). The decrease is

Table 1. pH-values observed in pig and human muscles at rest and after exercise

pH-value		
Rest	Exercise	Reference
Pig (M. longissimus dorsi)		
6.91	6.11	Löwe et al., 1977
7.2-7.3		Bendall, 1973
7.0		Tarrant et al., 1972
	[a] 6.06-6.28	Lindberg et al.,1973
	[b] 6.14-6.36	"
Human (M. quadriceps femoris)		
7.09	6.56	Sahlin et al., 1975
6.96		Hermanssen & Osnes, 1972
	6.4-6.6	Sahlin, 1986
	[c] 6.61	Sahlin & Henriksson,
	[d] 6.80	1984

[a] Untrained pigs [b] Trained pigs
[c] Untrained humans [d] Trained humans

caused by a breakdown of the glycogen and ATP stored in the muscles. As oxygen is not available, there is an anaerobic glycolysis where lactate is produced. The metabolic activity in the muscles causes an increased temperature in the carcass within the first hour pm. (Briskey & Wismer-Pedersen,1961). The environmental temperature has also an important influence on the rate of the chemical processes in the muscles after slaughter, and on the rate of the fall in pH and temperature (Wismer-Pedersen & Briskey, 1961; Kim, 1984; Lundberg & Vogel 1987; Møller et al., 1987).

When PSE develops in the carcass, pH drops to values lower than 5.8 already 45 minutes pm (Wismer-Pedersen, 1959; Scheper, 1971). The low pH in combination with a high car-

cass temperature causes the proteins in the muscles to denature (Wismer-Pedersen, 1959; Penny, 1967; Honikel & Kim, 1986). This contributes to the pale colour of PSE-meat (Wismer-Pedersen & Briskey, 1961; Martin et al., 1975; Honikel & Kim, 1986) and also to the reduced waterholding capacity (Wismer-Pedersen, 1959; Offer et al., 1988).

The purpose of this study was to compare normal and PSE carcasses concerning the muscle-pH at exsanguination and the rate of decrease in pH and temperature.

MATERIALS AND METHODS

pH and temperature

pH (Knick Portamess pH-meter 651-2, Berlin, BRD with Xerolyt^{R} geleelectrode; Dr W Ingold, Zürich, Schweiz) and temperature (Tastoterm D 700 Impac, Transfer, Sundbyberg, Sweden; electrode ET 1202) were continuously measured in the M. longissimus dorsi (LD), at the last rib, in 73 pig carcasses during 90 minutes pm.

The carcasses were randomly chosen from the normal slaughter at one slaughter-house. The pigs were electrically stunned (90 V, 0.8-1.0 A, 15 s.) and shackled by one hind foot at stunning. The carcasses remained shackled during the bleeding procedure. The scalding occurred 10 minutes pm.

In 32 carcasses (material 1) the measurements were made within the first 6 minutes after exsanguination, and were continued after scalding for every 5th minute. Before the carcasses were split, a cut was made with a scalpel through the rind and the electrode was put into the loin muscle. The carcasses were split along the spine at 30 minutes pm, and after the splitting measurements were made through the split vertebral column. At 50 minutes pm, the carcasses were placed in a chillingroom (-17 °C) for 60 minutes, and after that at +4 °C (Fig. 1).

The carcasses in material 2 (n=41) were monitored every minute during one hour, starting at 30 minutes pm. The measurements were made through the split vertebral column. At 50 minutes pm the carcasses were placed in a chillingroom, +4 °C (Fig. 1).

The carcasses were defined as normal or PSE (PSE $pH_{45} \leq 5.8$; Scheper, 1971).

Statistical analyses

The statistical analyses of the data was carried out with the Statistical Analysis System (SAS Institute Inc., 1985) using the GLM procedure. The GLM models used for comparing the slopes of the regression lines were as follows:

(1) Comparing the slopes for the decrease in pH at the time before 6 minutes pm and after 30 minutes pm within each quality class.

$$y_{ijk} = \mu + t_i + a_j + ta_{ij} + b_i x + e_{ijk}$$

where

y_{ijk} =the ijkth observation
μ =general mean
t_i =the effect of the ith time (i=1,2)
a_j =the effect of the jth animal (j=1,2...,26 or j=1,2...,5) $N\sim(0,\sigma^2_A)$
ta_{ij} =the effect of the interaction between the ith time and the jth animal $N\sim(0,\sigma^2_{TA})$
$b_i x$ =the linear regression of pH on time
e_{ijk} =residual random term, $N\sim(0,\sigma^2_e)$

The effect of time and the regression of pH on time was regarded as fixed and animal as random.

(2) Comparing the slopes for the decrease in pH and temperature between normal and PSE quality.

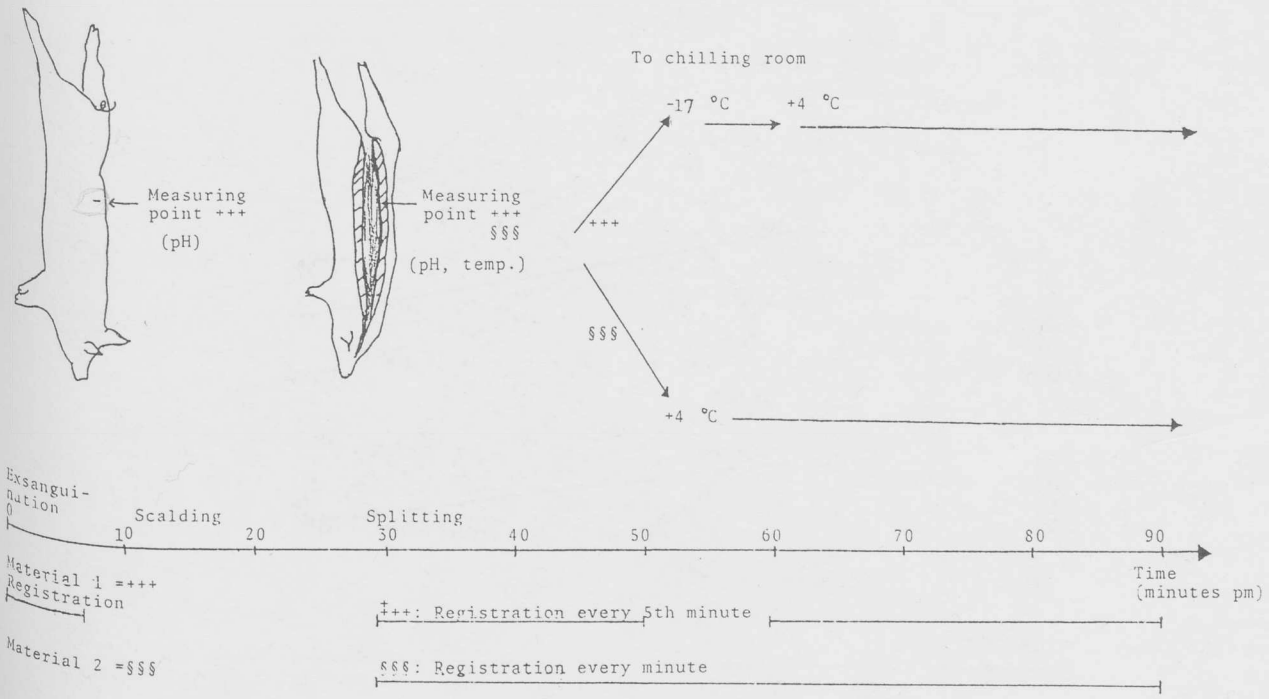

Figure 1. Time schedule for the various measures after slaughter.

$$y_{ijk} = \mu + c_i + a_{ij} + b_{1i}x + b_{2i}x^2 + e_{ijk}$$

where y_{ijk}, μ and e_{ijk} is the same as above and in addition:

c_i =the effect of the ith quality class (i=1,2)

a_{ij} =the effect of the jth animal within the ith quality class (j=1,2...,26 or j=1,2...,5) $N\sim(0,\sigma^2_A)$

$b_{1i}x$ =the linear regression of pH and temperature on time

$b_{2i}x^2$ =the quadratic regression of temperature on time

The effect of quality class and the regression of pH and temperature on time was regarded as fixed and animal as random.

RESULTS

Material 1

The relationship between the decrease in pH and time was found to be biphasic, and for normal carcasses the rate was significantly faster the first 6 minutes than after scalding (Table 2).

Table 2. The rate of decrease in pH in normal and PSE carcasses before 6 minutes and after 30 minutes pm in material 1

		b-value		
Quality	n	≤6 min	≥30 min	Sign. level
Normal	26	-0.0585	-0.00259	**
PSE	5	-0.0632	-0.00421	n.s.

Levels of significance: n.s. = not sigificant ($p>0.05$); ** = ($p\leq0.01$).

The non-significant difference for PSE carcasses, despite a large difference in b-values, is probably explained by the few carcasses in this group (n=5). Fig. 2 shows the regression lines between pH and time and the observations in both normal and PSE carcasses. In PSE carcasses the average pH at exsanguination and at 30 minutes pm was significantly lower than in normal carcasses.

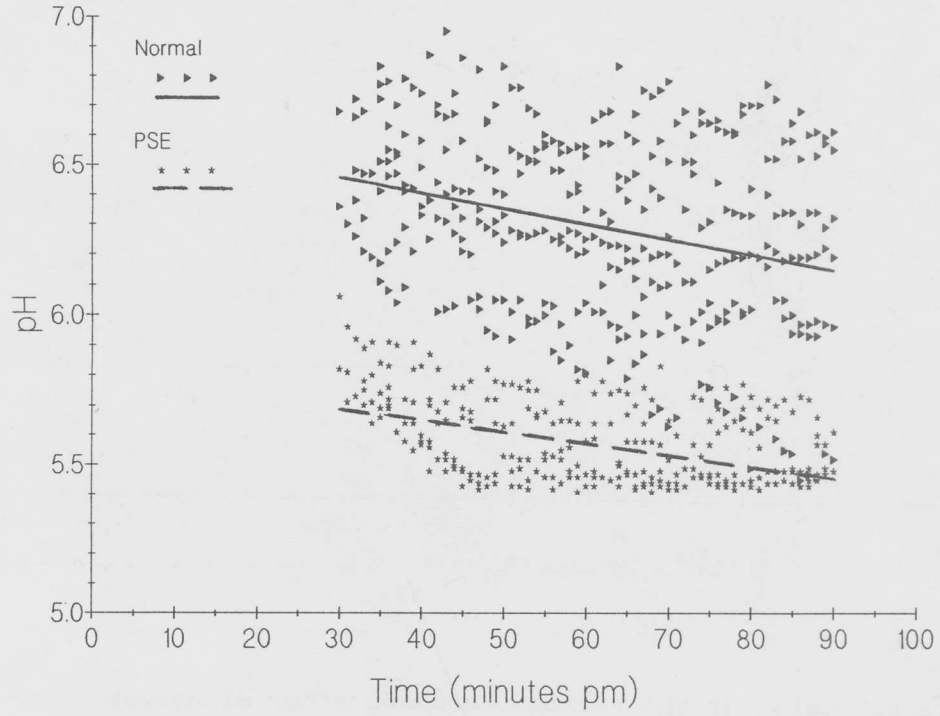

Figure 4. pH-observations in LD in carcasses with normal (n=32) and PSE (n=7) quality in material 2. The linear regression of pH on time is shown for both quality classes.

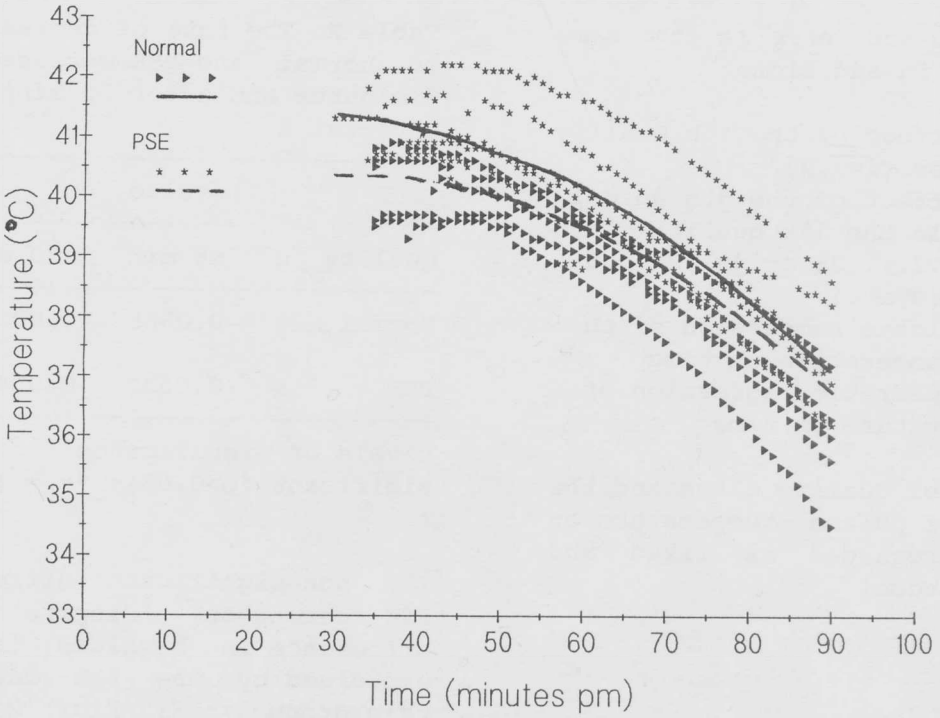

Figure 5. Changes of the temperature after slaughter in LD in normal and PSE carcasses in material 2. The observations shown is from 6 representative animals within each quality class. The quadratic regression of temperature on time is shown for both quality classes.

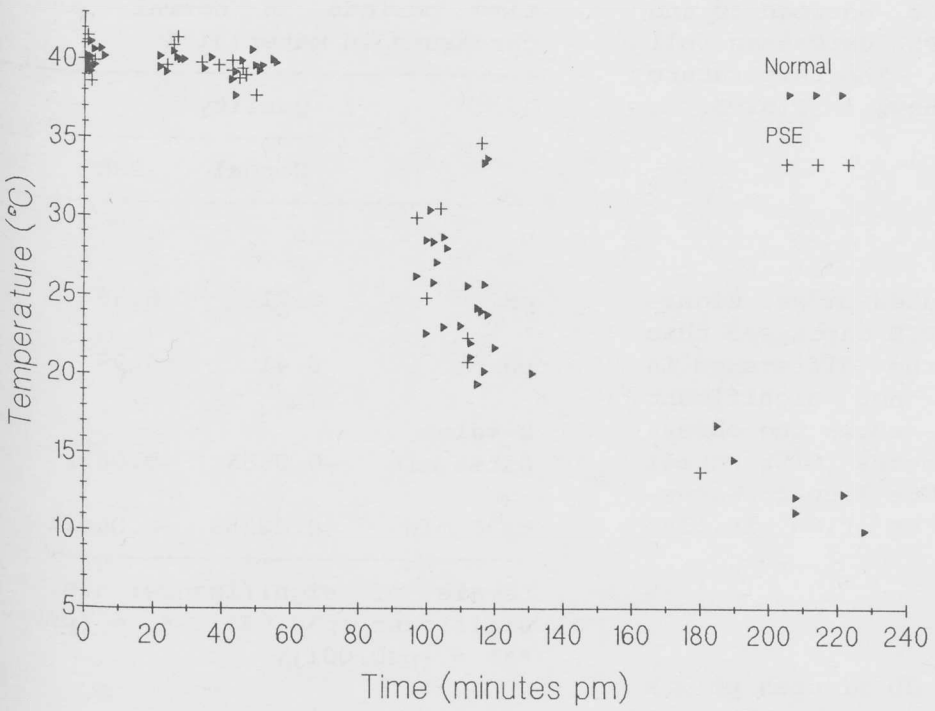

Figure 3. Observations of temperature in LD in normal and PSE carcasses in material 1.

normal quality. The regression of temperature on time for normal and PSE carcasses is shown in Fig. 5 together with observations from 6 representative carcasses within each quality class.

DISCUSSION

During stunning and exsanguination of pigs, large changes occur in the muscles. Tarrant et al. (1972) observed a change in pH from 7.0 in the living muscle to 6.3 at 5 minutes pm. Accordingly, it is important to make the registrations as soon as possible after bleeding to survey the post mortem reactions in carcasses. The conception "initial pH" is often used to describe the first registered pH value, independent of time. This is quite confusing when trying to compare results from different investigations.

The results from this study indicate that the muscle-pH at exsanguination is lower in carcasses which will develop PSE than in those with normal quality. Lundström et al. (1989) found higher lactate levels in the loin muscle immediately after exsanguination in pigs with nn and Nn halothane genotypes than those with NN. From these results it is possible to calculate the initial pH in the muscles as 6.92, 6.74 and 6.67 for animals with NN, Nn and nn genotype, respectively, using the formula

Table 4. pH at 30 min pm (pH_{30}) and the rate of fall in pH in LD for PSE and normal quality in material 2

	Quality		Sign.
	Normal	PSE	level
n	32	7	
pH_{30}	6.51	5.83	***
b-value	-0.0561	-0.00342	n.s.

Levels of significance: n.s. = not sigificant ($p>0.05$); ***=($p\leq0.001$).

There was no difference in the rate of the decreace in pH between PSE and normal carcasses during the first 6 minutes, but between 30 and 90 minutes the PSE carcasses fell faster (Table 3). The temperature observations are shown in Fig. 3.

Material 2

pH

The pH at 30 minutes pm was significantly lower in PSE carcasses than in normal, but the difference in fall of pH was not significant (Table 4). Fig. 4 shows the observations from carcasses with normal and PSE quality. The linear regression line for pH on time is also drawn.

Temperature

The temperature at 30 minutes pm was higher in PSE carcasses than in normal ($p \leq 0.05$; 41.1 vs 40.2). The change in temperature pm was best described with a second order equation, and there was a significant ($p \leq 0.001$) difference in slope between loin muscles with PSE and

Table 3. pH at exsanguination (pH_0) and 30 min pm (pH_{30}) and the rate of fall in pH in LD during different time periods in normal and PSE carcasses in material 1

	Quality		Sign. level
	Normal	PSE	
n	26	5	
pH_0	6.71	6.38	*
pH_{30}	6.41	5.99	***
b-value			
$0 \leq t \leq 6$ min	-0.0585	-0.0632	n.s.
$t \geq 30$ min	-0.00259	-0.00421	*

Levels of significance: n.s. = not sigificant ($p > 0.05$); * = ($p \leq 0.05$); *** = ($p \leq 0.001$).

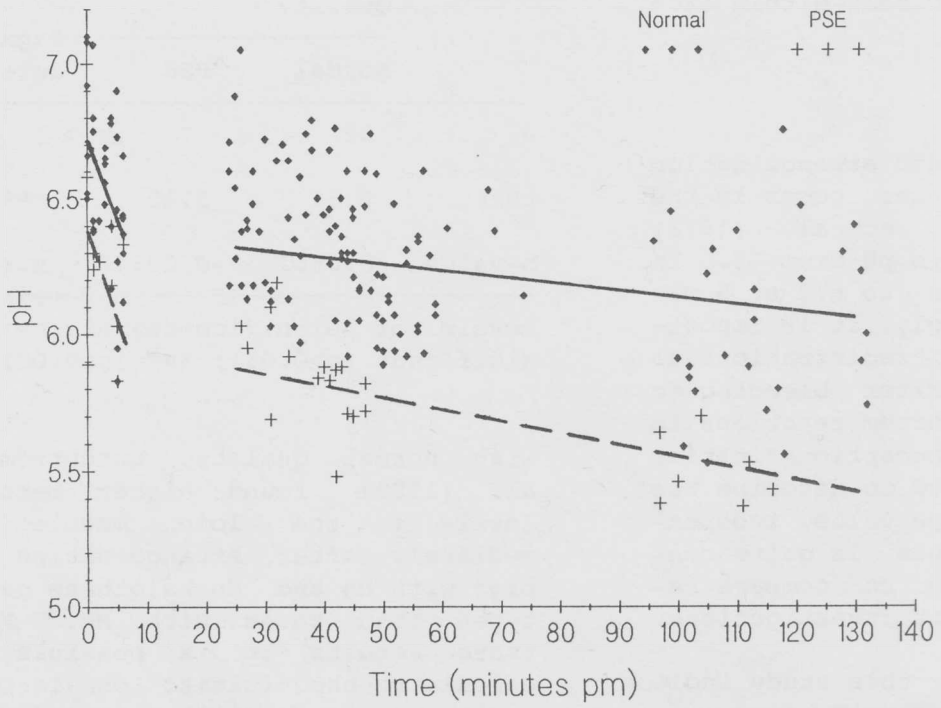

Figure 2. The decrease in pH in LD in normal(n=26) and PSE(n=5) carcasses in material 1 during 0-6 min pm and after 30 min pm.

given by Bendall (1973). Bendall et al. (1963) found significantly lower pH in PSE carcasses than in normal (6.66 vs 6.78) 10 minutes pm. As the PSE carcasses had a higher rate of decrease in pH between 10 and 200 minutes pm, they concluded that there could not have been any difference in the pH between normal and PSE when extrapolating to the time at exsanguination. The pH could, however, have been lower in the PSE carcasses already at exsanguination.

In our study, there was a higher rate in the fall of the pH in PSE carcasses in material 1, but the difference between the slopes for normal and PSE was significant only after 30 minutes pm. Although the PSE carcasses in material 2 tender to have a slightly slower rate, no significant difference in the rate of decrease in pH between normal and PSE carcasses was observed. That was probably due to the low level of pH which was reached already when the measurements begun. The lower pH was combined with a significantly higher temperature at 30 min pm in the PSE carcasses.

Biphasic pattern of fall in pH has been reported by Tarrant et al. (1972), who observed a higher rate of fall in pH the first hour pm than between 1 and 4 hours pm. Bendall et al. (1963) found an increased rate when pH reached 6.5 in carcasses with normal quality, but PSE carcasses did not have this change in rate. It thus seems that the rate of the fall of pH changes with time and actual pH-level. It would be desirable to determine the exact time/pH-level when the rate changer, if any. The present study indicates that there is a change whithin the first 30 minutes pm. As the carcasses usually are scalded at that time, investigations of the exact pH-decrease are difficult from a practical point of view.

When calculating the rate of the fall in pH, one should have in mind that the unavoidable damage of the muscle tissue caused by the insertion of the electrode can influence the post mortem glycolysis and the fall of pH (Hofmann, 1987). The rate of the decrease in pH in this study agrees quite well with results from others (Bendall et al., 1963; Hallund & Bendall, 1965; Tarrant et al., 1972). The rate is probably somewhat faster in PSE carcasses, but it may be the combination with a lower pH at exsanguination that initiates the development of meat with PSE caracteristics. The difference in pH level at the start of the slaughtering procedure seems very interesting and ought to be further investigated.

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