FURTHER INVESTIGATIONS INTO RELATIONSHIPS BETWEEN MEASUREMENTS CARRIED OUT ON THE SLAUGHTER LINE AND PIG MEAT QUALITY THE DAY AFTER SLAUGHTER

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INTRODUCTION

Previous work carried out at the Danish Meat Research Institute has shown that measurements of rigor, pH_1 and temperature carried out on the slaughter line could not be used to predict which pigs would develop PSE- or DFD-meat in commercial experiments. While most pigs with PSE-meat showed early rigor development, low pH_1-values and higher than normal muscle temperatures 45 mins. after slaughter, many other pigs with exactly the same measurements showed a good meat quality the day after slaughter (Barton-Gade, 1979). Further work (Barton-Gade, 1978) showed that pre-slaughter treatment affected the relationships concerned. Pigs with an absolute minimum of physical and psychological stress before slaughter showed good relationships between slaughter line measurements and meat quality characteristics. However, when pigs received a "normal" treatment, i.e. transport on a lorry, holding period in the pens, etc., these good relationships no longer existed, and measurements of rigor and pH_1 could not be used as predictors of PSE-meat.

These results were given the following interpretation: Pigs with sufficient energy reserves at the point of slaughter will be able to show their heritable disposition for meat quality. Meat quality will therefore show maximum variation for the group of pigs concerned, and relationships between slaughter line measurements and meat quality characteristics will be good and those expected from theory. If, however, pigs have used a certain amount of their energy reserves before slaughter, then they could not always show their heritable disposition for meat quality. The variation in meat quality characteristics will fall, and relationships between slaughter line measurements and meat quality characteristics will no longer be good. All the above-mentioned work was carried out on pigs, which did not show DFD-meat, so that a final judgement on the usefulness of slaughter line measurements could not be made. This paper describes further investigations using Danish progeny testing pigs as experimental material.

MATERIALS AND METHODS

The experimental material consisted of 2006 Danish Landrace pigs slaughtered at about 90 kg live weight. The pigs, which were all tested on one station, were slaughtered over a period of 18 months after a standardised pre-slaughter treatment (Barton, 1974).

All pigs were investigated for the following:

Slaughter line about 45 mins. after slaughter

1. Rigor in the semimembranosus (SM) muscle (Sybesma, 1966) - higher values corresponding to a greater degree of rigor
2. Colour/structure in SM and the gluteus medius (GM) muscle subjectively: 1 = extremely PSE, 2 = PSE, 3 = slightly PSE, 4 = normal
3. pH_1 in SM, GM, longissimus dorsi (LD) at the 13th rib and the semispinalis capitis (SC) muscles

The day after slaughter

1. Colour (reflectance at 535 nm) in the uncured biceps femoris (BF) and cured LD muscles (Barton, 1972)
2. Subjective evaluations of the structure of these muscles using the above 4-point scale, each sample being judged 6 times and the result given as the average
3. pH_2-values in SM, BF, quadriceps femoris (QF), LD, serratus ventralis (SV), SC and triceps brachii (TB) muscles

Colour measurements and subjective evaluations of structure are thus carried out in 2 typically "white" muscles, which are particularly prone to the PSE-condition, while pH_2-values are measured in 7 muscles, 3 typically "red" (QF, SV, SC), 3 typically "white" (SM, BF, LD) and one intermediate (TB), so that a good impression of the DFD-status of the carcass is obtained. The total impression of the PSE- and/or DFD-status of each pig was estimated using the following scheme:

PSE-status						DFD-status
Group	Description	Colour value		Subjective structure		Number of muscles with higher than normal pH_2-values
		Uncured BF	Cured LD	Uncured BF	Cured LD	
Extremely PSE	Both muscles extremely PSE or one extremely PSE, the other PSE	>19.7 >16.5	>15.0 >18.6			0,1,2,3,4,5 or 6
PSE	Both muscles PSE	16.6 - 19.7	15.1 - 18.6			0,1,2,3,4,5 or 6
Slightly PSE	One of the muscles PSE, the other acceptable	<16.6 >16.5	>15.0 <15.1			0,1,2,3,4 or 5
Tendency to PSE	One or both muscles with a tendency to PSE with the subjective evaluation but colour values good	<16.6	<15.1	4.0 <3.7 3.8 <3.7 <3.7	<3.7 4.0 <3.7 3.8 <3.7	0,1,2,3,4,5 or 6
Not PSE	None, or only single comments of "slightly PSE" with the subjective evaluation. Colour values good			4.0 3.7/3.8 4.0 3.8	4.0 4.0 3.7/3.8 3.8	0,1,2,3,4,5,6 or 7

The above limits for colour values were determined experimentally and are valid for Danish Landrace only. pH_2-values ≥ 5.70 (LD), ≥ 5.80 (SM), ≥ 5.90 (BF and TB), ≥ 6.10 (QF, SV) and ≥ 6.30 (SC) are considered to be higher than normal for pigs with the standardised pre-slaughter treatment.

In the few cases where the BF or LD muscle had higher than normal pH_2-values, the PSE-group was determined using the muscle which was not DFD. Within this scheme pigs which were "Not PSE" or showed a "Tendency to PSE" with 0 or 1 muscle with pH_2-values higher than normal are considered to have a completely acceptable meat quality. Pigs, which were "Extremely PSE" or "PSE", are considered to be PSE, while pigs were considered to be DFD if 5 of the 7 muscles had higher than normal pH_2-values.

RESULTS

Correlation coefficients Relationships between individual slaughter line measurements and meat quality characteristics, expressed as correlation coefficients, were generally low to medium (r = 0.2 - 0.5). One of the reasons for this was that the relationships were not linear. High rigor values were found in pigs which developed either PSE- or DFD-meat. pH_1-values in "white" muscles showed good relationships with colour values up to a pH_1-value of 6.0, whereafter there was little change with increasing pH_1. Similarly, there was little relationship between pH_1 in the "red" muscle, SC, and pH_2-values in "red" muscles in the pH_1-range 5.5 to 6.3, whereas the relationships were much better in the range 6.4 to 7.1. Attempts were made to express the above relationships using multiple correlation coefficients. However, there were such highly significant interactions between the various slaughter line measurements themselves, that this approach was rejected.

Grouping according to meat quality the day after slaughter Grouping the experimental material using the scheme described under "materials and methods" showed, as could be expected, that the number of PSE-pigs decreased rapidly with increasing DFD-status. The most reliable estimation of the relationship between PSE-group and slaughter line measurements was therefore obtained from pigs with DFD-status 0 or 1. Similarly, the most reliable estimate of the relationship between DFD-status and slaughter line measurements was obtained using pigs which were "Not PSE".

Table 1. Slaughter line measurements for PSE-groups with DFD-status 0 or 1.
Averages, which are significantly different ($p < 0.05$), are given different superscripts.

PSE-group	No. of pigs	Rigor SM	Colour/structure		pH_1-value				Colour/value	
			SM	GM	SM	GM	LD	SC	Uncured BF	Cured LD
Extremely PSE	100	8.8^{a}	3.1^{a}	2.8^{a}	5.58^{a}	5.46^{a}	5.48^{a}	6.03^{a}	20.5^{a}	18.5^{a}
PSE	136	8.9^{a}	3.4^{b}	3.1^{b}	5.68^{b}	5.51^{a}	5.49^{a}	6.08^{a}	18.2^{b}	16.6^{b}
Slightly PSE	354	7.8^{b}	3.8^{c}	3.7^{c}	5.92^{c}	5.76^{b}	5.79^{b}	6.14^{b}	17.1^{c}	14.4^{c}
Tendency PSE	449	7.0^{c}	4.0^{d}	3.9^{d}	6.17^{d}	6.02^{c}	5.98^{c}	6.17^{b}	14.9^{d}	12.7^{d}
Not PSE	415	6.2^{d}	4.0^{d}	4.0^{d}	6.37^{e}	6.27^{d}	6.15^{d}	6.21^{bc}	13.8^{e}	12.4^{d}

Table 1 shows that with increasing severity of the PSE-condition, the pigs showed earlier rigor development, became paler and more exudative and had lower pH_1-values in "white" muscles. The differences were generally highly significant, the exceptions being the groups "Extremely PSE" and "PSE", which were not different for rigor and most pH_1-values, and the groups "Tendency to PSE" and "PSE", which were not different for colour and structure. pH_1-values in the SC muscle showed a smaller decrease with increasing severity of the PSE-condition than "white" muscles did, but even here the extremes were significantly different from one another.

Table 2 shows the comparison of DFD-groups for pigs which were not PSE. It can be seen that with increasing severity of the DFD-condition, the pigs showed earlier rigor development, a tendency to lower pH_1-values in "white" muscles, and an increase in the pH_1-value of the SC muscle. The difference between DFD-groups was not always significant, but in general DFD-group 0 was always significantly different from DFD-groups 6 and 7. Colour and structure were more or less always normal on the slaughter line for all DFD-groups.

Table 2. Slaughter line measurements for DFD-groups for pigs which are not PSE
Averages, which are significantly different (p 0.05), are given different superscripts.

DFD-status	No. of pigs	Rigor SM	Colour/structure		pH_1-value				pH_2-value						
			SM	GM	SM	GM	LD	SC	SM	BF	QF	LD	SV	SC	TB
0	278	5.9^{a}	4.0	4.0	6.40^{a}	6.30^{a}	6.18^{a}	6.20^{a}	5.48^{a}	5.57^{a}	5.76^{a}	5.47^{a}	5.94^{a}	5.96^{a}	5.70^{a}
1	137	6.8^{b}	4.0	4.0	6.30^{b}	6.20^{b}	6.09^{b}	6.23^{a}	5.50^{b}	5.64^{b}	5.98^{b}	5.50^{b}	6.12^{b}	6.19^{b}	5.77^{b}
2	103	7.2^{b}	4.0	3.9	6.31^{b}	6.14^{bc}	6.08^{b}	6.33^{b}	5.53^{c}	5.69^{c}	6.10^{c}	5.51^{b}	6.26^{c}	6.36^{c}	5.80^{b}
3	107	8.1^{c}	3.9	3.9	6.27^{b}	6.13^{bc}	6.15^{ab}	6.47^{c}	5.55^{cd}	5.77^{d}	6.24^{d}	5.54^{c}	6.37^{d}	6.48^{d}	5.90^{c}
4	57	8.4^{c}	3.9	3.9	6.19^{b}	6.10^{bc}	6.02^{b}	6.53^{cd}	5.58^{d}	5.83^{e}	6.38^{e}	5.55^{c}	6.44^{e}	6.58^{e}	6.03^{d}
5	42	8.9^{c}	4,0	4.0	6.30^{ab}	6.17^{bc}	6.17^{ab}	6.56^{d}	5.71^{e}	6.07^{f}	6.46^{f}	5.62^{d}	6.51^{f}	6.63^{f}	6.17^{e}
6	20	10.1^{d}	3.9	3.8	6.21^{b}	5.97^{c}	6.00^{b}	6.59^{d}	5.86^{f}	6.17^{g}	6.51^{g}	5.75^{e}	6.54^{f}	6.70^{g}	6.27^{f}
7	5	8.6^{cd}	4.0	4.0	6.40^{ab}	6.46^{bc}	6.36^{ab}	6.66^{cd}	5.96^{g}	6.29^{h}	6.64^{h}	5.86^{f}	6.55^{ef}	6.69^{h}	6.24^{ef}

Tables 1 and 2 show that the relationships between slaughter line measurements and meat quality characteristics are on average those expected from theory. However, dividing the experimental material into various groups of slaughter line measurements/evaluations and calculating the meat quality for each of these, gives a much less clear cut picture. For any one combination of slaughter line measurements, pigs from nearly all meat quality groups could be found, although some types predominated with certain combinations.

Evaluations of colour and structure on the slaughter line, even though they showed good relationships with meat quality characteristics, could not be used in practice as predictors of meat quality because there were so few pigs which deviated from normal with respect to this characteristic. In any case there was a significant interaction between colour/structure and pH_1-values. Concentrating on pH_1-values and rigor 45 mins. after slaughter, and using various pH_1-limits for "white" and "red" muscles respectively, 78% of the PSE-pigs, 73% of the DFD-pigs and 79% of the pigs with completely acceptable meat quality could be predicted (Table 3). While PSE- and DFD-pigs could be clearly distinguished from one another, there was a considerable overlap between these 2 groups and pigs with an acceptable meat quality.

Table 3. The best combination of rigor and pH_1-values for the separation of pigs with a PSE-, DFD- and an acceptable meat quality

See "materials and methods" for the definition of PSE-, DFD-, and acceptable meat quality. Note that a few of these pigs fell outside the rigor/pH_1-groups shown in the table, so that the percentages do not add up to 100.

Rigor 45 mins. after slaughter	pH_1-value		% of PSE-pigs (N = 197)	% of DFD-pigs (N = 69)	% of pigs with acceptable meat quality (N = 855)
	"white" muscles average	SC			
In rigor/partially in rigor	<5.8	All	77.7	1.5	10.2
Not in rigor	<5.8	<6.5			
All	⩾5.8	⩾6.5	0.5	72.5	10.1
All	⩾5.8	<6.5	20.8	26.1	78.7

These 3 meat quality groups could not be separated more clearly in this experiment because 41 of the 197 PSE-pigs (20.8%) and 18 of the 69 DFD-pigs (26.1%) did not show the expected slaughter line pattern. The atypical PSE-pigs were not in rigor on the slaughter line, they were normal in appearance and pH_1-values in "white" muscles were significantly higher than in other PSE-pigs (Table 4). The atypical DFD-pigs were not in rigor on the slaughter line either and pH_1-values were also higher than in other DFD-pigs (Table 4).

Table 4. Comparison of PSE- and DFD-pigs with atypical slaughter line measurements and other PSE-/DFD-pigs
Averages which are significantly different ($p<0.05$), are given different superscripts.

Group	No. of pigs	Rigor	Colour/ structure		pH_1-value				Colour/ value		pH_2-value					
		SM	SM	GM	SM	GM	LD	SC	Uncured BF	Cured LD	SM	BF	QF	LD	SV	SC TB
Atypical PSE-pigs	41	5.5^a	4.0^a	4.0^a	6.01^a	5.81^a	5.67^a	6.11	18.8	17.2	5.44	5.49^a	5.66^a	5.36^a	5.85^a	5.80^a 5.61^a
Other PSE-pigs	156	9.5^b	3.2^b	2.8^b	5.56^b	5.42^b	5.44^b	6.03	19.3	17.4	5.44	5.52^b	5.72^b	5.41^b	5.91^b	5.88^b 5.67^b
Atypical DFD-pigs	18	5.7^c	4.0	4.0	6.56^c	6.47^c	6.39^c	6.57	11.6	12.7	5.75	6.05^c	6.45	5.67	6.51	6.57^c 6.17
Other DFD-pigs	51	10.5^d	3.9	3.9	6.17^d	5.99^d	6.04^d	6.59	11.3	12.1	5.78	6.13^d	6.50	5.67	6.53	6.68^d 6.21

21% of the PSE-pigs and 26% of the DFD-pigs could not therefore be distinguished from many pigs with an acceptable meat quality using slaughter line measurements. The higher pH_1-values in the atypical PSE- and DFD-pigs was probably due to their rigor values, as there was a clear relationship between these 2 slaughter line measurements for any one meat quality, the greater the degree of rigor, the lower the pH_1-values. The question can thus be limited to why these atypical pigs did not show early rigor development.

2 atypical PSE-pigs and 5 atypical DFD-pigs were slaughtered during the first 6 months of the experiment, so that a within-litter comparison was not possible. The other atypical PSE- and DFD-pigs came from 33 and 13 litter groups respectively. One boar had 2 litter groups with atypical PSE-pigs and one had a litter group with an atypical PSE-pig and one with an atypical DFD-pig. 3 boars were grandsires to 15 of the 33 PSE litter groups and 4 of the 13 DFD-groups. More than one atypical pig was found in 7 of the PSE litter groups and 1 of the DFD-groups. However, there were just as many litter groups with other PSE- or DFD-pigs, which showed the expected slaughter line pattern (7 PSE-groups and 2 DFD-groups).

Atypical PSE-pigs were often slaughtered on the same day (2 days with 4 pigs, 4 days with 3 pigs, 4 days with 2 pigs and 11 days with 1 pig), while atypical DFD-pigs were only seldom so (3 days with 2 pigs and 7 days with 1 pig). On 3 separate occasions both atypical PSE- and DFD-pigs occurred. Over 80% of the atypical PSE-pigs were slaughtered during the warmer months of the year, while the atypical DFD-pigs were slaughtered over the whole year.

DISCUSSION

The pigs in this experiment have probably had a pre-slaughter treatment which in many ways is more "normal" than any of the experimental groups in the previous experiment. Among other things, leaving the home pen, loading onto a lorry, transport and off-loading at the slaughterhouse were quite new to the pigs. The special factors in the pre-slaughter treatment of Danish progeny testing pigs are the efforts made to ensure that the pigs have as high energy reserves as possible at the point of slaughter. Thus, the pigs have access to feed up to the point of collection; they are transported in a lorry with partitions, non-skid floors and mechanical ventilation, and slaughter normally begins within 10 mins. of arrival at the slaughterhouse.

Regardless of these arrangements, progeny testing pigs must have used more of their energy reserves than pigs with the minimal stress in the previous experiment. That progeny testing pigs generally have good relationships between slaughter line measurements and meat quality characteristics shows among other things that the pre-slaughter treatment must allow the pigs to show their genetic disposition for meat quality.

Even though slaughter line measurements on average showed good relationships with meat quality characteristics in progeny testing pigs, they could not be used in practice to accurately predict which pigs would develop PSE- or DFD-meat, because 21% of the PSE-pigs and 26% of the DFD-pigs showed such an atypical slaughter line pattern, that they could not be distinguished from many pigs with a completely acceptable meat quality. In practical experiments with Danish commercial pigs, therefore, none of the usual methods of measuring meat quality on the slaughter line can be used as predictors of PSE- or DFD-meat, partly as a result of a more prolonged pre-slaughter treatment and partly as a result of atypical PSE- and DFD-pigs. This conclusion is in agreement with some research workers (Martin, et al. (1975), Rahelić et al. (1978), but does not agree with others (see e.g. Scheper & Schön, (1971), Scheper, et al. (1979).

The presence of these atypical pigs seemed to be due to both genetic and environmental factors in this work, but the experimental procedure did not allow a complete explanation of the phenomenon.

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