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The Effect Of Handling Pre-Slaughter And Carcass Processing Rate Post-Slaughter On Pork Quality

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ABSTRACT

Forty-eight male crossbred (Large White—Landrace) pigs were used in a 2×2 factorial design to determine the effect of pre-slaughter handling (minimal and negative handling prior to slaughter) and the rate of carcass processing post-slaughter [normal rate (45 min) and delayed rate (70 min) from time of exsanguination to carcass entering the chiller] on muscle glycolysis and pork quality. Pigs negatively (using an electric goad) handled at the abattoir just prior to slaughter had lower muscle glycogen concentrations in the Longissimus thoracis *(LT) and the* Biceps femoris *(BF) at all times post-slaughter and lower lactic acid at 5, 45 and 70 min post-slaughter compared to pigs minimally (no use of electric goads) handled prior to slaughter. Negative handling of pigs just prior to slaughter also resulted in pork which had higher surface exudate and a higher incidence of PSE compared with pigs minimally handled prior to slaughter. A prolonged rate of carcass processing resulted in reduced muscle glycogen in the LT and BF at all times post-slaughter. Delays in carcass processing rate also affected pork quality, as the meat was paler in comparison with pig carcasses that were processed without any delays. The results from this experiment have indicated that the use of electric goads to move pigs at the abattoir, and delays in carcass processing post-slaughter, can have a detrimental influence on ultimate pork quality.* © *1998 Elsevier Science Ltd. All rights reserved*

INTRODUCTION

Pre-slaughter handling of pigs from the farm to the abattoir, and at the abattoir can have a major influence on pork quality (Moss, 1984). Under normal circumstances, there is a gradual decline in muscle pH post-slaughter until the onset of *rigor mortis* at about 6–8 hr post-slaughter. However, if pigs are acutely stressed prior to slaughter, then muscle glycogenolysis is increased by adrenergic mechanisms resulting in increased muscle temperature and an increased rate of muscle pH decline post-slaughter (Moss, 1984) and can lead

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to pale, soft, exudative (PSE) pork. Hence the use of electrical goads to move pigs on-farm and at the abattoir prior to slaughter has the potential to negatively affect pork quality and increase the incidence of PSE pork (Grandin, 1991). The economic loss associated with PSE pork is estimated to cost the Australian pig industry approximately $20 million annually (Whan, 1993).

The rate of temperature decline in the carcass also affects the post-slaughter glycolytic rate due to the extreme temperature-dependence of the reaction (Lawrie, 1991). Thus any factors which affect the rate of temperature decline in the carcass have the potential to cause or exacerbate PSE. The recommended standards for evisceration and carcass processing suggest that evisceration should commence within 20 min of exsanguination (Maynard and Warner, 1996). The recommended maximum time from stunning of the animal to entry of the carcass into the chiller is 45 min (Maynard and Warner, 1996). Although the average time from stun to chiller in most abattoirs is below 45 min, a recent audit of Australian abattoirs has shown that carcass processing rates vary considerably (Maynard and Warner, 1996). The main causes of delay in carcass processing in Australian abattoirs appears to be due to pigs being left on the line during staff recesses, manual handling of carcasses on the evisceration line and mechanical breakdowns on the evisceration line.

The aim of this experiment was to determine the effect of the interaction between pre-slaughter handling of pigs and the post-slaughter rate of carcass processing on muscle glycolysis and subsequent pork quality.

MATERIALS AND METHODS

Animals and feeding

Forty-eight male crossbred (Large White×Landrace) pigs with a mean liveweight of 95 kg (range ± 10 kg) were selected and blocked into 4 replicates (based on liveweight) of 12 pigs each. The experimental pigs were fed *ad libitum* a commercial ration (17·8% crude protein (CP) and 14·4 MJ kg^{-1} digestible energy (DE)) and had *ad libitum* access to water via a nipple drinker. The pigs in each replicate were slaughtered on separate days.

Experimental design

The experiment had a 2×2 factorial design with the respective factors being handling (minimal and negative handling just prior to slaughter) and post-slaughter carcass processing rate [normal (45 min) and delayed (70 min) processing rates]. The pigs were randomly assigned to the four treatments within each replicate and transported 0·5 km to the research abattoir in groups of 3 (experimental unit = 3 pigs). After 15 hr lairage at the abattoir with access to water (time off feed), the pigs were individually subjected to their handling treatment at the abattoir just prior to slaughter. The minimal handling treatment involved using minimal force (e.g. gentle coaxing) to move the pigs from the holding yards to the slaughter area. Electric goads were not used and negative handling was kept to an absolute minimum. The pigs in the negative handling treatment were given 15 electric shocks (3V input) with an electric goad during the 5 min prior to slaughter.

All pigs were stunned using a carbon dioxide dip-lift stunner (Butina, Denmark) set at 85% CO_2 and for 1·8 min exposure. After the pigs were exsanguinated and scalded, the carcasses in the normal processing rate group were eviscerated and split before entering the chillers at approximately 45 min post-slaughter. The carcasses in the delayed processing rate group were exsanguinated and scalded as above. However, after scalding, these

carcasses were left hanging on the slaughter line for 20 min after which the carcasses were eviscerated and split before entering the chillers at approximately 70 min post-slaughter.

Sample collection and pork quality assessment

Muscle samples (~1 g) for glycogen and lactic acid determination were collected from the *Longissimus thoracis* (LT) between the 12th/13th rib and from the *m. biceps femoris* (BF) at 5 min, 45 min, 70 min and 24 hr post-slaughter, and immediately frozen in liquid nitrogen and stored at −80°C. Muscle glycogen concentration was determined by the colourimetric method described by Dreiling *et al.* (1987). Muscle lactic acid was determined using a commercial diagnostic kit (Sigma Chemical Company, St Louis, Missouri, USA). All glycogen and lactic acid analyses were conducted in single assays and the intra assay coefficient of variation for glycogen was 7·8% and for lactic acid was 2·3%. The pH and temperature of the LT and BF were determined at 45 min, 70 min and 24 hr post-slaughter using a portable pH/temperature meter (Jenco Electronic Ltd, Model 6009) fitted with a polypropylene spear-type gel electrode (Ionode IJ42S, Brisbane, QLD) and a temperature probe. The surface exudate of the LT and BF was measured 24 hr post-slaughter using the filter paper absorption method (filter paper—55 mm) (Kauffman *et al.*, 1986). Surface lightness (L^*) of the LT muscle was measured with a Minolta Chromameter CR-200, using D65 illumination, a 2° standard observer and 8 mm aperture in the measuring head. Pigs were classified as PSE if the LT muscle had drip loss values > 5% and surface lightness L* values > 50 (Warner *et al.*, 1993). A value of 100 mg surface exudate was used as an equivalent of 5% drip loss (55 mm filter papers; Warner, Pers. comm.) for determining the water holding capacity in PSE carcasses.

Statistics

Data were analysed by ANOVA (Payne *et al.*, 1993) to examine the main effects of pre-slaughter handling (H), post-slaughter carcass processing rate (CP), muscle type (M) and their interactions (2-way) on muscle glycogen, lactic acid and pork quality indicators. The frequency of PSE and DFD carcasses was analysed using the chi-square goodness of fit test (Snedecor and Cochran, 1980).

RESULTS

Muscle glycogen and lactic acid concentrations

Muscle glycogen and lactic acid concentrations and glycogenolysis rates for the LT and BF muscle are presented in Table 1. Pigs negatively handled at the abattoir had lower ($p < 0{\cdot}001$) muscle glycogen in the LT and BF at 5 min, 45 min, 70 min and 24 hr post-slaughter compared to pigs that were minimally handled at the abattoir just prior to slaughter. The LT and BF muscle had similar ($p > 0{\cdot}05$) muscle glycogen concentrations at 5 min and 24 hr; however, the LT had higher ($p < 0{\cdot}05$) muscle glycogen concentrations at 45 min and 70 min post-slaughter compared with the BF muscle. Pig carcasses with a delayed processing rate had lower ($p < 0{\cdot}05$) muscle glycogen concentrations at 5 min, 45 min, 70 min and 24 hr post-slaughter, compared with the carcasses with a normal processing rate. As the carcass processing treatment was not imposed at 5 min post-slaughter, the lower glycogen concentration at 5 min post-slaughter is presumably an anomaly. Pre-slaughter handling, post-slaughter carcass processing rate and muscle type did not affect ($p > 0{\cdot}05$) the rate of muscle glycogenolysis (expressed as change in muscle glycogen

TABLE 1
The Effect of Handling Pre-slaughter and Carcass Processing Rate Post-slaughter on Muscle Glycogen and Lactic Acid Concentrations and Glycogenolytic Rates in the *Longissimus Thoracis* (LT) and *Biceps Femoris* (BF) Muscle of Pigs

	Handling[a] *(H)*		*Carcass Processing Rate*[b] *(CP)*		*Muscle*[c] *(M)*			*F Probability*		
	Minimal	*Negative*	*Normal*	*Delayed*	*LT*	*BF*	*sed*	*H*	*CP*	*M*
Glycogen (mg/g)										
5 min	9·7	7·6	9·0	8·3	8·87	8·4	0·342	< 0·001	0·027	0·208
45 min	7·3	4·9	6·6	5·5	6·4	5·7	0·309	< 0·001	0·001	0·043
70 min	4·9	3·3	4·6	3·6	4·5	3·7	0·266	< 0·001	< 0·001	0·007
24 hr	1·4	0·8	1·3	1·0	1·1	1·1	0·175	< 0·001	0·046	0·968
Glycogenolysis Rate 1[d]	0·06	0·07	0·06	0·07	0·06	0·07	0·008	0·356	0·413	0·524
Glycogenolysis Rate 2[d]	0·08	0·05	0·07	0·07	0·06	0·07	0·009	0·003	0·957	0·673
Glycogenolysis Rate 3[d]	0·0025	0·0018	0·0024	0·0019	0·0024	0·0019	0·0002	0·001	0·012	0·010
Lactic Acid (mg/g)										
5 min	2·2	3·0	2·7	2·5	2·6	2·6	0·180	< 0·001	0·362	0·704
45 min	2·8	3·8	3·5	3·2	3·4	3·2	0·241	< 0·001	0·096	0·217
70 min	3·5	4·5	4·1	3·9	4·2	3·7	0·203	< 0·001	0·199	0·015
24 hr	7·7	7·8	8·1	7·4	7·7	7·9	0·343	0·696	0·061	0·633

[a]Handling; Minimal = minimal handling treatment just prior to slaughter, Negative = negative handling treatment just prior to slaughter.
[b]Carcass Processing Rate; Normal = 45 min carcass processing rate, Delayed = 70 min carcass processing rate.
[c]Muscle; LT = *Longissimus thoracis*, BF = *Biceps femoris*.
[d] Change in glycogen concentration/min; Rate 1—change in concentration between 5 min and 45 min; Rate 2—change in concentration between 45 min and 70 min; Rate 3—change in concentration between 70 min and 24 hr.

concentration per minute) for the time period 5 min to 45 min post-slaughter. However, pigs minimally handled pre-slaughter had a greater ($p < 0{\cdot}01$) rate of glycogenolysis for the time period 45 min to 70 min post-slaughter and 70 min to 24 hr post-slaughter in comparison with pigs negatively handled prior to slaughter. Also, pig carcasses processed without delays had higher ($p < 0{\cdot}05$) rates of glycogenolysis (70 min to 24 hr post-slaughter) compared to carcasses with delayed processing. The LT muscle also had a higher ($p < 0{\cdot}05$) rate of glycogenolysis (70 min to 24 hr post-slaughter) compared to the BF muscle. The muscle lactic acid concentrations indicate that pigs negatively handled at the abattoir, had higher ($p < 0{\cdot}001$) muscle lactic acid in the LT and the BF muscle at 5 min, 45 min, 70 min, but not at 24 hr ($p > 0{\cdot}05$) post-slaughter compared to pigs which were minimally handled at the abattoir just prior to slaughter. There was no difference ($p > 0{\cdot}05$) in muscle lactic acid concentrations at all times post-slaughter between carcasses with a normal or delayed processing rate.

Post-slaughter muscle temperature

Post-slaughter muscle temperatures are presented in Table 2. Pigs negatively handled at the abattoir had higher ($p < 0{\cdot}05$) muscle temperature in the LT and BF muscle at 45 min and 70 min but not ($p > 0{\cdot}05$) at 24 hr post-slaughter compared with pigs that were minimally handled at the abattoir just prior to slaughter. However, carcass processing rate did not have any effect ($p > 0{\cdot}05$) on post-slaughter muscle temperatures in either the LT and BF muscles. The BF muscle had higher ($p < 0{\cdot}001$) temperatures at all times post-slaughter compared with the LT muscle.

Pork quality indicators

Pork quality data are presented in Table 3. Pigs that were negatively handled at the abattoir had lower ($p < 0{\cdot}05$) muscle pH in the LT and BF muscle at 45 min and 70 min, but not ($p > 0{\cdot}05$) at 24 hr post-slaughter, than pigs that were minimally handled at the abattoir just prior to slaughter. However, carcasses with a normal or delayed processing rate had similar ($p > 0{\cdot}05$) muscle pH in the LT and BF muscle at all times post-slaughter. The LT muscle had a lower ($p < 0{\cdot}05$) muscle pH at 45 min and 24 hr post-slaughter compared with the BF muscle. While negative handling prior to slaughter did not ($p > 0{\cdot}05$) affect surface lightness, carcasses with a delayed processing rate had paler meat

TABLE 2
The Effect of Handling Pre-slaughter and Carcass Processing Rate Post-slaughter on Muscle Temperature in the *Longissimus Thoracis* (LT) and *Biceps Femoris* (BF) Muscle of Pigs

	Handling[a] *(H)*		*Carcass Processing Rate*[b] *(CP)*		*Muscle*[c] *(M)*			*F Probability*		
	Minimal	*Negative*	*Normal*	*Delayed*	*LT*	*BF*	*sed*	*H*	*CP*	*M*
Temperature (°C)										
45 min	39·2	40·1	39·6	39·6	39·0	40·2	0·179	< 0·001	0·829	< 0·001
70 min	36·6	37·9	36·9	37·6	35·3	39·2	0·426	0·002	0·090	< 0·001
24 hr	2·4	2·4	2·4	2·4	2·1	2·8	0·0881	0·944	0·906	< 0·001

[a]Minimal = minimal handling treatment just prior to slaughter, Negative = negative handling treatment just prior to slaughter.
[b]Normal = 45 min carcass processing rate, Delayed = 70 min carcass processing rate.
[c]Muscle; LT = *Longissimus thoracis*, BF = *Biceps femoris*.

TABLE 3
The Effect of Handling Pre-slaughter and Carcass Processing Rate Post-slaughter on Pork Quality Indicators in the *Longissimus Thoracis* (LT) and *Biceps Femoris* (BF) Muscle of Pigs

	Handling[a] *(H)*		*Carcass Processing Rate*[b] *(CP)*		*Muscle*[c] *(M)*			*F Probability*		
	Minimal	*Negative*	*Normal*	*Delayed*	*LT*	*BF*	*sed*	*H*	*CP*	*M*
pH 45 min	6.40	6.25	6.32	6.33	6.39	6.27	0.048	0.002	0.930	0.015
pH 70 min	6.20	6.07	6.17	6.11	6.18	6.10	0.060	0.033	0.374	0.217
pH 24 hr	5.62	5.62	5.62	5.61	5.59	5.64	0.019	0.946	0.847	0.014
Lightness (L*)	47.2	48.1	47.0	48.3	51.2	44.0	0.478	0.069	0.007	< 0.001
Exudate (mg)	74.5	104.6	86.9	92.2	88.1	91.0	7.740	< 0.001	0.489	0.700
% PSE in LT[d]	9	41	25	25				0.050	0.910	

[a]Minimal = minimal handling treatment just prior to slaughter, Negative = negative handling treatment just prior to slaughter.
[b]Normal = 45 min carcass processing rate, Delayed = 70 min carcass processing rate.
[c]Muscle; LT = *Longissimus thoracis*, BF = *Biceps femoris*.
[d]Chi-square goodness of fit test used.

($p < 0{\cdot}05$) compared with pigs with a normal processing rate. In addition, the BF muscle was darker ($p < 0{\cdot}05$) than the LT muscle. Pigs negatively handled at the abattoir had higher ($p < 0{\cdot}001$) surface exudate in both the LT and BF muscles compared with pigs that were minimally handled at the abattoir just prior to slaughter. The rate of carcass processing did not affect ($p > 0{\cdot}05$) surface exudate in the LT or BF and both the LT and BF muscle had similar ($p > 0{\cdot}05$) surface exudate. Also, pigs that were negatively handled at the abattoir had a higher ($p = 0{\cdot}05$) frequency (41% vs 9%) of PSE meat compared with pigs that were minimally handled at the abattoir just prior to slaughter.

DISCUSSION

Use of electric goads by stockpersons to move pigs from lairage pens to the stunning area can acutely stress pigs and increase plasma adrenaline and noradrenaline concentrations (Troeger and Woltersdorf, 1989). One of the consequences of increased plasma adrenaline and noradrenaline secretion is increased neuromuscular stimulation resulting in increased glycogenolysis (Lister *et al*., 1981). The increased post-slaughter muscle metabolism that occurred in negatively handled pigs in this experiment, as indicated by lower muscle glycogen and higher lactic acid concentrations at 5 min post-slaughter, the higher post-slaughter muscle temperatures and the lower post-slaughter muscle pH is consistent with that reported by Lister *et al*. (1981). The lower muscle glycogen concentrations at 5 min and 45 min and the absence of any significant difference in the rate of glycogenolysis between 5 and 45 min post-slaughter in negatively handled pigs suggests that the negatively handled pigs had lower muscle glycogen concentrations prior to slaughter rather than an increased rate of glycogenolysis between 5 min and 45 min post-slaughter compared with minimally handled pigs. Therefore, a better indication of the rate of glycogen mobilisation due to negative handling would be the change in glycogen concentrations occurring from the onset of the handling to 5 min post-slaughter. However, this is difficult to determine under experimental conditions as immobilisation of the animal to obtain a biopsy muscle sample to determine 'resting' muscle glycogen concentrations would 'stress' the animal thereby influencing the animals' response to the pre-slaughter handling treatment. The higher glycogenolytic rate (between 70 min and 24 hr post-slaughter)

occurring in carcasses processed at a normal rate appears to be due to the presence of higher muscle glycogen concentrations in both the LT and BF at 70 min and 24 hr post-slaughter compared with carcasses processed at a delayed rate which had significantly lower muscle glycogen concentrations for the same time periods.

The higher exudate and the incidence of PSE pork in negatively handled pigs further confirms that the use of an electric goad to move animals just prior to slaughter can have a detrimental effect on pork quality. These data are in agreement with those of Grandin (1980) who reported that acute stress such as electric shocks from an electric goad can result in meat which has high drip loss and incidence of PSE. Conversely, others have reported that the use of an electric goad on pigs prior to slaughter had little effect on pork quality. Guise and Penny (1989) reported that the use of electric goads during loading/unloading pigs as well as while moving pigs to the slaughter area resulted in skin blemishes but had little effect on the paleness of meat. Similarly, Hatton and Ratcliff (1973) have also reported that the use of electric goads on pigs prior to slaughter had little effect on muscle reflectance and colour. The lack of consistency between pork quality data presented in this paper and studies reported by Hatton and Ratcliff (1973) and Guise and Penny (1989) may be due to the variation in a pig's response to an acute stressor, difference in the intensity of the stressor, and previous handling experience the pigs might have been subjected to. The studies reported by Hatton and Ratcliff (1973) and Guise and Penny (1989) also investigated the influence of other pre-slaughter factors such as transport and stocking density on meat quality and a possible interaction between the above factors could have masked any influence of handling on pork quality.

Delays in carcass evisceration resulted in carcasses entering the chillers later than the generally recommended time of less than 45 min. Unlike pre-slaughter negative handling, delays in carcass processing rate, while affecting muscle glycogen concentrations, did not affect muscle lactic acid, temperature or pH values. However, there was an effect on muscle surface lightness. The absence of any difference in muscle lactic acid concentrations, pH and temperature in carcasses with delayed processing rates suggests that perhaps the delay in carcass evisceration used in this experiment may not have been severe enough to significantly influence muscle metabolism. However, the increased paleness in carcasses with a delayed processing rate suggests it is more likely that the chilling regime used in this experiment may have aided in overcoming any potential problems associated with delays in carcass cooling. Delays in carcass processing rates have previously been reported to result in paler meat (Eldridge *et al.*, 1993), as found in this experiment, although they also reported a higher drip loss. Conversely, other studies have reported that the processing time from stun to chilling had little effect on the carcass temperature, post-slaughter muscle glycogen and lactic acid concentrations, and pork quality (Honkavaara, 1989).

Muscle type can also play a significant role in determining pork quality, with differences in muscle glycogen concentrations (45 and 70 min post-slaughter), pH and surface lightness being attributed to structural and metabolic characteristics of the LT and BF muscle. While the LT and BF predominantly consist of type IIB (intermediate) muscle fibres, the lower surface lightness L* values in the BF muscle in this experiment are possibly as a result of the higher pigment content in this muscle (Leseigneur-Meyneir and Grandemer, 1991). The anatomical locations of the LT and BF muscle could also account for differences in muscle temperature. The evisceration and splitting of the carcasses prior to entry to the chiller aided the rate of cooling of the LT muscle compared to the BF muscle which was not exposed (still had skin/fat layer) and hence had higher post-slaughter temperatures.

These data indicate that delays in carcass processing rate reduced muscle glycogen concentrations at 5 min post-slaughter. As the carcass processing treatment was not

imposed at this time and as the pigs were randomly allocated to their respective pre- and post-slaughter treatments, it is likely that this is an anomalous result which has no apparent explanation. Also, as a result of the increased glycogen breakdown, higher muscle temperature and inferior pork quality, it appears that negative handling had a greater influence on muscle metabolism and subsequent pork quality than delays in carcass processing rate.

Overall, the findings from this experiment indicate that acute stress such as negative handling of pigs with an electric goad can lead to increased muscle glycogenolysis, as well as increased inferior pork quality. Delays in carcass evisceration can also affect pork quality and result in paler meat. While pre-slaughter negative handling appears to have a greater influence on rate of muscle metabolism and pork quality compared to post-slaughter factors such as delays in carcass evisceration, proper pre- and post-slaughter management is required to consistently produce pork of high quality.

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