Comparison of the effects of different transport conditions and lairage times in a Mediterranean climate in South Africa on the meat quality of commercially crossbred Large white × Landrace pigs

L C Hoffman[a*] and P Fisher[a,†]

ABSTRACT

Information on the effect of road transportation conditions and lairage times on the meat quality of pork under South African conditions is very sparse. In this investigation, the effects of 2 road conditions (rough road with frequent stops – A; smooth road, few stops – B) and 2 lairage holding periods (2 h and 24 h) on the physical meat quality attributes of commercially produced pigs during summer (ambient temperatures >30 °C) in the Western Cape (South Africa) were investigated. Pig meat from pigs transported on a road that caused more stress (A), had lower pH_{45} (measured 45 min *post mortem*) values after 2 h lairage than pigs transported over a smoother road. Pigs B had a lower muscle pH_{24} (measured 24 h post mortem) than group A, indicating that they had more glycogen reserves available for *post mortem* glycolysis. Road conditions A were more stressful resulting in a higher incidence of PSE pork, as shown by the percentage drip loss and the L* values. When the lairage period was increased to 24 h prior to slaughter, pigs transported under road conditions A had time to replenish their energy reserves and the pH_{45}, drip loss and L* values were within an acceptable range. However, pigs transported under road conditions B had lower pH_{45} and higher pH_{24} values, indicating that the lairage period was too long and that energy reserves were depleted in order to adapt to the stressful conditions. Results from this investigation indicate that improvement of the transport/road conditions will result in better pork quality.

Keywords: colour, drip loss, lairage, pH, pig meat, transport.

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INTRODUCTION

The effect of pre-slaughter handling on ultimate meat quality of pigs has been widely researched and reported on[3,6,10,15,17,21,23,25,26]. Pre-slaughter handling (time of last feeding, transport, lairage, stunning) affects meat quality by influencing both the rate and the extent of acidification of the muscles *post mortem.* The extent of the decline in pH is determined largely by the energy concentration (glycogen) present in the muscle at death. A combination of high carcass temperature and a rapid rate of lactic acid formation immediately *post mortem* normally leads to protein denaturation and a resultant drop in water holding capacity (WHC), as well as a pale colour, which are all typical features of pale, soft and exudative (PSE) meat[10,23]. Using a board to move pigs during slaughtering *versus* using an electrical prod almost halved the occurrence of PSE meat due to the effect of a decrease in stress[15]. If pre-slaughter stress is more chronic, as opposed to acute stress that leads to PSE, muscle glycogen will be depleted at the time of death and the decline in pH will be limited, thus leading to dry, firm and dark (DFD) meat[23,28].

Experiments on the effect of time of last feeding and different holding periods (lairage) indicated that pigs that have been fed prior to slaughter, combined with a short holding period, gave higher frequencies of PSE meat than pigs with no feeding and a prolonged holding period[20]. However, the prevalence of DFD meat was higher in the unfed pigs and increased during the first couple of hours of the holding period[20]. By manipulating the feeding and holding period, the prevalence of both DFD and PSE meat can be minimised. This can be achieved by slaughtering unfed pigs immediately after unloading and slaughtering fed pigs after approximately 4 h holding time in the lairage. Holding in the lairage may have negligible or no influence on meat quality, particularly in pigs that have not been subjected to stress caused by factors such as handling and transportation, or are resistant to stress[28]. In a study comparing lairage times ranging from 0 to 24 h, the author reported that the lowest incidence of PSE was after a lairage period of 8 h rest, and the highest after no lairage rest[27]. The results indicated that a lairage time of not less than 6 h is recommended. Other studies indicated that the risk of PSE increased if lairage time increased above 10 h but that minor changes (2 %) in the risk of PSE occur between 3 to 10 h of lairage, and that lairage times up to 6 h decreased the incidence of carcasses with low initial pH values[1,8]. Longer holding times resulted in a slight increase in DFD carcasses. It was found that overnight lairage caused an increase in the incidence of DFD meat, as well as a slight increase in PSE, the latter being difficult to explain.

In South Africa, very little work has been conducted on the effect of transport conditions and lairage time on pork quality. An investigation of 6 abattoirs in the Highveld Region in South Africa noted that there were marked differences in vehicle design and road conditions during the transport of the pigs[26]. It was also noted that the various abattoirs had no fixed rule regarding lairage holding time[26]. In South Africa, a frequently asked question is: which lairage period is most suitable to ensure a minimal decrease in carcass quality, particularly in hot summer periods? An additional factor that further exacerbates the decrease in carcass quality is the fact that not all South African roads have a smooth surface, thereby causing potential stress on animals that are trying to maintain their balance while being transported on these roads[26,29]. Additionally, it has been found that the use of vehicles aimed at providing better animal welfare conditions are of great importance[7]. It has been reported that animals can recover adequately from transport stress if they are rested for an appropriate

[a]Department of Animal Sciences, University of Stellenbosch, Private Bag X1, Matieland, 7602 South Africa.

[†]Present address: Roche Vitamins South Africa (Pty) Ltd, PO Box 2, Isando, 1600 South Africa.

*Author for correspondence.
E-mail: lch@sun.ac.za

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amount of time and through proper handling at the abattoir facilities[30,31]. Also, transit time may affect the incidence of PSE with transit times of less than 2 h increasing the risk of PSE while longer transit times will decrease the risk of PSE[8]. This is thought to be because longer transit times allow the pigs to recover from the stress of loading as well as giving them time to adapt to their new environment[22].

The aim of this study was to determine the effect of road transportation conditions and lairage holding times on the meat quality of commercially crossbred Large white × Landrace pigs in summer and to propose suitable pre-slaughter handling practices that would improve meat quality.

MATERIALS AND METHODS

Animals

The pigs from both producers used in this experiment were malignant hyperthermia negative Landrace × Large white crossbreds. The live slaughter weight was approximately 90 kg and a total of 149 pigs were divided into 4 groups:

Gr 1, 40 pigs carried on road A (see below), 2 hour lairage.

Gr 2, 40 pigs, road A, 24 hour lairage.

Gr 3, 38 pigs, road B, 2 hour lairage.

Gr 4, 31 pigs, road B, 24 hour lairage.

Prior to slaughtering, feed was withdrawn from the pigs for a period of 12 h. Each producer's pigs originated from a single pen. The pigs from both producers were transported to the abattoir in an open truck with slatted sides and a slatted floor to avoid slipping and injury during transport, with each producer's pigs being transported separately. The transport route of road A was 35 km and took 45 min, with the road being a combination of dirt roads with speed bumps (7 km), urban traffic, paved roads and highways. Transport time and distance for road B were 30 min and 25 km respectively, with the route taken being a combination of paved roads and highways with minimal stops due to traffic control measures.

The pigs were transported in the early morning to avoid high ambient summer temperatures and offloaded at the abattoir using a height-adjustable ramp. Unloading from the trucks to the lairage pens and from the pens to the slaughter area was done without electrical prodders. The pigs were housed in roofed pens with drinking water freely available *via* drinking nipples. The pigs were slaughtered before 08:00 each day in accordance with approved procedures. This consists of electrical stunning (160 V AC, 1.25 A, ear to ear for 3–5 seconds) and sticking within 30 seconds. The carcasses were spray scalded in a warm water shower with a regulated temperature of 60 °C. Hair was removed by mechanical tumbling. This was followed by evisceration and inspection of the carcasses by the authorised meat inspection personnel. After the initial measurements were taken (pH_{45}, warm carcass weight, percentage predicted lean content) the carcasses were chilled at 2 °C for 24 h after which additional measurements (pH_{24}, drip loss, colour) were taken. All measurements and samples were taken on the left side of the carcass.

Physical measurements

The pH values (pH_{45} and pH_{24}) of the *M. longissimus thoracis* (MLT) were measured using a hand held Crison pH/mV-506 meter equipped with a glass electrode. Before use, the pH meter and electrode were calibrated in pH 4 and pH 7 buffers, the latter being at the appropriate temperatures (35 °C and 4 °C, respectively). The pH meter was re-calibrated after every 4th reading and the electrode rinsed with distilled water between each measurement. The pH meter contained a temperature probe ensuring automatic adjustment of the pH for temperature. The measuring point on the carcass was defined as a point between the 2nd and 3rd last thoracic vertebra, 45 mm from the midline, with the actual measurement taken in MLT at a similar depth (± 35 mm). The initial pH was measured 45 min after stunning (pH_{45}), with the ultimate pH (pH_{24}) measured after chilling for 24 h.

The percentage predicted lean content was determined with a Hennessey Grading Probe, measuring fat and muscle thickness between the 2nd and 3rd last thoracic vertebrae 45 mm from the midline, according to the current South African classification system[5].

For colour and drip loss measurements 2 slices of the MTL, 25 mm thick, were removed from the anterior end of the left side of each carcass at the position of the 6th thoracic vertebra. Drip loss was determined according to the procedure described by Honikel[10], with the samples weighed individually and placed, under atmospheric pressure, in a net enclosed in a polythene bag in such a manner that the exudate did not come into contact with the sample, but collected in the bag. The samples were stored for 48 h at 2 °C, after which they were removed, touch dried with tissue paper and reweighed. An additional drip loss determination was done with the 2nd sample consisting of a circular cut portion of the MLT 3 cm in diameter and weighing approximately 30 g, as described by Kauffman *et al.*[14]. The procedures to determine drip loss on these samples were similar to that described by Honikel[10]. Drip loss is reported as the weight loss as a percentage of the original weight of the sample for both types of drip loss determination. Colour was measured using a hand held Gardner colorimeter (D65 illumination, 10° aperture) to determine L*, a* and b* values[2]. Fresh meat colour was determined on a portion of the MLT after blooming for 1 hour as described by Honikel[12].

Statistical analysis

ANOVA was performed on all the variables measured using the General Linear Models (GLM) procedure of SAS[24]. A full model was used to determine the presence of any 2-way interaction (within each pig producer/road). The model is $Y_j = \mu + L_j + e_j$, where Y_j = dependent variable, μ = overall mean, L_j = lairage time effect, and e_j = residual. Differences between the variables were reported as being significant if the probability of rejection of $H_o < 5\ \%$.

RESULTS

The mean values of the carcass and meat quality characteristics measured for the pigs from both producers are presented in Table 1. Analysis of the carcass data only indicate a difference ($P \leq 0.05$) in warm carcass weight between the highest and lowest means (road A, 24 h lairage *vs* road B, 24 h lairage), with fat thickness and lean content showing only a small variation ($P > 0.05$) between the 4 groups. Road × lairage time interaction was insignificant for all carcass quality characteristics (warm carcass weight, fat thickness and percentage predicted lean content).

Comparison of the initial pH values (pH_{45}) shows a dissimilar pattern between roads, with the pigs travelling on road A that were rested for 24 h having higher pH_{45} values ($P \leq 0.05$) compared with those slaughtered after 2 h of lairage holding. The results for road B show the opposite, with the pigs held for 24 h having lower initial pH values ($P \leq 0.05$) compared with those slaughtered after only 2 h. The difference between road conditions (and thus the pre-slaughter environment prior to offloading at the abattoir) on pH_{45}, when comparing the results for the 2 h lairage time, is significantly different, with the pigs from road B having a higher mean pH_{45} when compared with road A. The significant differences in pH_{24} values showed an opposite trend to those for pH_{45}. Both drip loss measurements (measured both as a portion of the loin which included fat and

Table 1: **Comparison of carcass and meat quality characteristics of pigs from road A and B subjected to 2 lairage times (mean ± s.e).**

Carcass and meat quality characteristics	Lairage time			
	Road A		Road B	
	2 h (n = 40)	**24 h** (n = 40)	**2 h** (n = 38)	**24 h** (n = 31)
Warm carcass weight	70.17 ± 1.13	72.13 ± 1.16	69.13 ± 1.16	66.99 ± 1.29
Fat thickness (T_{23} – 45 mm)	16.20 ± 0.68	17.19 ± 0.70	17.52 ± 0.70	16.23 ± 0.77
% Predicted lean content	67.90 ± 0.32	67.43 ±0.33	67.07 ± 0.33	67.70 ± 0.36
pH_{45}	5.81^b ± 0.06	6.11^a ± 0.06	6.20^a ± 0.06	6.01^b ± 0.07
pH_{24}	5.79^a ± 0.02	5.68^b ± 0.02	5.48^b ±0.02	5.77^a ± 0.03
Drip loss (whole loin portion)	2.20 ± 0.16	2.21 ± 0.16	2.15^a ±0.16	1.43^b ± 0.18
Drip loss (MLT portion)	12.04^a ± 0.50	7.29^b ± 0.52	8.88^a ± 0.52	6.92^b ± 0.57
L*	60.44 ± 0.60	59.92 ± 0.62	58.65^a ± 0.62	56.41^b ± 0.68
a*	4.62 ± 0.25	4.55 ± 0.26	4.85^a ± 0.26	3.54^b ± 0.28
b*	11.90 ± 0.28	11.77 ± 0.29	11.21^a ± 0.29	10.17^b ± 0.32

^{a,b}Row means, for each road, with different superscripts differ significantly ($P \leq 0.05$).

bone and the MLT alone), was lowest for the pigs from road B which were rested for 24 h when compared with the pigs in the other 3 groups. Comparing drip loss from the MLT between lairage times within road factors does indicate that lairage for 24 h reduces drip loss significantly. Means for reflectance (L*) and colour (a* and b*) values suggest a similar pattern to that of both drip loss measurements, with the pigs from road B having the lowest means for the descriptive colour values of all 3 groups. Resting for 24 h does show a decrease in L*, a* and b* values when comparing lairage times between roads, but only differing ($P \leq 0.05$) for road B.

DISCUSSION

The effects of pre-slaughter handling, and more specifically transport distances and lairage holding times, on meat quality of pigs have been well documented [9,13,19,20,30]. However, these results often seem to be in conflict with respect to the effect on ultimate meat quality when measured as drip loss, colour, and pH (both initial and ultimate). The accuracy of the results from this investigation, conducted in a commercial environment following procedures currently practised by South African producers and abattoirs alike, is limited by the fact that road transportation effects could not be separated from producer effects. The latter include factors such as diet composition, handling procedures during loading, different genetics, etc. However, owing to the limited extent of pig production in South Africa, it can be accepted that genetic variation between producers is small. Furthermore, standard husbandry protocols were practised by both producers. Thus, differences in meat quality detected in the present study could partly be attributed to stress caused by road transportation and lairage times.

The initial and ultimate pH values from road A (2 h lairage period) show a very small reduction between pH_{45} and pH_{24} (Table 1), suggesting that the pigs were fatigued upon arrival at the abattoir, whereas the pigs from road B (2 h lairage period) had a high initial pH (6.20), which dropped to 5.48, the lowest of all 4 groups. This would suggest that enough energy-rich substrates (e.g. glycogen) were available in the muscles of the latter group at slaughter and, together with the high muscle temperatures, *post mortem* glycolysis proceeded uninterrupted until all the glycogen was depleted[23]. It has been hypothesised that the rate of pH fall is reduced when temperature declines, but that the rate of pH fall is independent of temperature above approximately 37 °C due to the optimal activity of metabolic enzymes at 39 ± 2 °C[18]. Subsequent work confirmed that a reduction in temperature early *post mortem* does lead to a reduction in the rate of pH decline, rather than the presence of high glycogen reserves which was postulated to keep metabolic rates high and thus increase heat production[16]. However, these results did not show any significant advantageous effects of early *post mortem* cooling on reduction of protein denaturation or drip loss, although there were tendencies toward lower drip loss in the MLT of cooled carcasses[16]. Another possible explanation for the considerable decline in pH is that, although slaughter took place early in the morning, the carcasses were chilled in chilling rooms with a capacity of approximately 450 carcasses. This places a considerable strain on the chilling facilities during the hot summer months (maximum ambient temperatures >30 °), which leads to carcasses not being cooled down rapidly enough, contributing to the development of high drip loss and reflectance values. Earlier work has shown that the earlier and faster the temperature is reduced, the larger the reduction in drip loss, due to a reduction in myosin denaturation in fast glycolysing muscle[11]. *Post mortem* muscle temperature measurements have not been included in the current study and warrant further investigation.

The results for the other meat quality characteristics (drip loss and colour) suggest that not only a rapid decline in pH, but also low initial pH values could result in high drip loss and reflectance (L*) values. The high mean drip loss (measured as a portion of the MLT) and L* values for the pigs transported on road A and held in lairage for 2 h are probably due to the combination of acute *ante mortem* stress and high carcass temperatures *post mortem.* By contrast, the pigs transported *via* road B and held for 2 h, showed significant improvements in drip loss ($P \leq 0.001$) and reflectance (L*) values ($P \leq 0.05$), even if the ultimate pH was lower and the range of decline in pH was higher. Since the animals from both producers were malignant hypothermia negative, the result must undoubtedly be due to transport conditions[23], with more severe effects in the case of road A. The results of this study support those of a previous study, which noted that the use of initial pH values alone as an indicator of stress, or meat quality, is not sufficient, since Hampshire pigs (or pigs exhibiting a similar decline pH pattern due to either genetic or environmental factors), despite having normal initial pH values and rates of pH fall, show an abnormally low ultimate pH, leading to a deterioration in meat quality[4].

The pigs from road B, held for 24 h, showed the best results for drip loss (both methods) and reflectance (L*), which could be partially explained by the combination of initial pH and the reduced decline in pH compared with the other groups (Table 1). This would suggest that protein denaturation was not as severe as in the other groups, resulting in less exudation and lower reflectance values.

The increase in lairage holding times from 2 to 24 h did result in lower mean drip loss values (measured as a portion of the MLT) for both roads, which is in agreement with other studies[20]. However, when drip loss is measured using a portion of the loin (including fat and bone) the differences are insignificantly small, except for the pigs held for 24 h from road B. This could probably be explained by the composition of the sample, which, consisting of muscle, bone and fat, will lose moisture predominantly from the muscle portion (where *post mortem* glycolysis takes place). Proportionally, the loss of moisture from this sample will then be less compared with the sample consisting solely of the MLT.

Despite limitations due to experimental design, analysis of the data from the present trial illustrated that transportation stress under South African conditions affected the physical meat quality traits of pigs. Extending lairage times can reduce drip loss, but the influence on initial and final pH presented different trends associated with different road conditions. Thus, the magnitude of the meat quality differences suggests that the benefit of increased lairage times on meat quality will not necessarily be worth the extra capital outlay for increasing lairage facilities. It would be more cost effective if more attention was paid to actual transport conditions and, as far as possible, to avoiding any situations or practices that will lead to deterioration in meat quality. Careful handling of pigs during the pre-slaughter phase, together with adequate lairage facilities, will greatly diminish the otherwise unavoidable detrimental effects (e.g. transport) on meat quality without necessitating large financial outlays.

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