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Effects of transportation time, distance, stocking density, temperature and lairage time on incidences of pale soft exudative (PSE) and the physico-chemical characteristics of pork

C.S. Gajana [a], T.T. Nkukwana [a], U. Marume [b], V. Muchenje [a,*]

[a] Department of Livestock and Pasture Science, Faculty of Science and Agriculture, University of Fort Hare, P Bag X 1314, Alice, 5700, South Africa
[b] Department of Animal Sciences, Faculty of Agriculture, Science and Technology, North West University, P Bag X2046, Mmabatho, North West Province, South Africa

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ABSTRACT

The study determined the effects of transportation time, distance, stocking density, temperature and lairage time on incidences of PSE and pork quality. Frequencies of PSE cases in stocking density categories within transport duration classes were determined. General linear models, regression and the principal component (PC) analysis were used to analyse the data. Highest incidences of PSE were recorded in autumn season while lowest incidences were recorded in the spring season. Transportation time and stocking density significantly affected pH_u and ultimately PSE incidences although there were no interactive effects. Highest risks of PSE occurrence were observed with more space allowance. The highest incidences of PSE were observed for animals that had travelled for two hours while the PSE cases were lower in animals that travelled for longer times. Distance travelled and transportation time had significant effects ($P < 0.05$) on thawing loss (TL) % of pork. No relationships were reported between the other pre-slaughter variables and pork quality attributes. With the exception of transportation time and distance travelled which had a positive relationship with TL%, variation in other pre-slaughter variables did not affect meat quality variables. The risks of PSE occurrence were dependent on stocking density and transportation time.

1. Introduction

Appropriate pre-slaughter handling of pigs is very important, not only from a welfare point of view, but also from a pork quality point of view. The way animals respond to pre-slaughter stress depends on breed, age and the season of slaughter (Muchenje, Dzama, Chimonyo, Strydom, & Raats, 2009; Muchenje & Ndou, 2011). Crowding, loading and unloading, adverse weather conditions, feed and water deprivation, lairage, length of travel, mixing animals from different groups, restraint, and fatigue are the causatives of stress (Adenkola, Ayo, Sackey, & Minka, 2008; Dalla Costa et al., 2007; Ritter et al., 2007). Indicators of pre-slaughter stress are commonly evaluated in terms of behaviour, biochemical function, endocrine and pathological variables (Ferlazzo, 2003). When pigs are stressed, their glycogen content is reduced thus, leads to lower lactic acid production and therefore results in meat with higher ultimate pH (pH_u) (Muchenje, Dzama, Chimonyo, Strydom & Hugo et al., 2009; Ndou, Muchenje, & Chimonyo, 2011). High pH_u (>6.0) values appear when animals are subjected to chronic stress and use up all their energy preventing sufficient lactic acid from reaching muscle pH values lower than 6.0 ultimately resulting in dark firm dry (DFD) meat (Purchas, Silva Sobrinho, Garrick, & Lowe, 2002). An ideal pH_u for meat ranges from 5.5 to 5.8 (Nanni Costa, Lo Fiego, Dall'Olio, Davoli, & Russo, 1999). This pH produces the neutral and desirable properties for table cuts (Simmons et al., 2000). However, variation in ultimate pH influences the meat quality characteristics such as colour, shelf-life, water holding capacity and technological yields (Gispert et al., 2000).

Meat colour is the most important factor affecting consumer acceptance, purchasing decisions and satisfaction of meat products (Verbeke, 2000; McCarthy, Boer, O Reilly, & Cotter, 2003). Colour measurements are done using the Commission International De I' Eclairage (CIE) colour system (Commission International De I' Eclairage, 1976). The three fundamental colour coordinates are L^*, a^* and b^*. The L^* measures the lightness and is a measure of the light reflected (100 = white; 0 = black); a^* measures positive red, negative green and b^* measures positive yellow, negative blue (Commission International De I' Eclairage, 1976). Carcasses with L^* value 49–60 were classified as normal pork quality, L^* values from 42 to 48 were classified as DFD pork and carcasses with L^* values 60–66 classified as pale soft exudative (PSE) pork (Warriss & Brown, 1993, 1995). However, when the muscle glycogen is used up rapidly during the handling and transport, pre-slaughter period and after slaughter, there is little lactic acid production which results in DFD meat. This condition is measured by L^* coordinates (Commission International De I' Eclairage, 1976).

* Corresponding author. Tel.: +27 40 602 2059; fax: +27 86 628 2967.
E-mail address: vmuchenje@ufh.ac.za (V. Muchenje).

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Pigs should be managed according to a chain assurance quality protocol avoiding established risk factors during transport and lairage by the control of parameters such as the driver's experience, transport time, stocking density on truck, offloading time, group size in lairage, stocking density and lairage time, produce meat of a better quality (Simmons et al., 2000). The meat quality response to pig handling in the 24 h before slaughter is very important in determining the yield of the carcass and the technological quality of meat for the processing industry (Alvarez, Garrido, & Banon, 2009; Lammens et al., 2007). There is no doubt that poor environmental conditions during pre-slaughter handling, while the animals are still alive, can irreversibly affect the quality of the meat. Furthermore, quality can be improved with the knowledge of these processes and guaranteed only through adequate control of different stages before slaughter (Alvarez et al., 2009).

There are no common recommendations in the literature for ideal pre-slaughter handling procedures for achieving the highest quality and yield of pork meat from small holder abattoirs. Most studies on improving meat eating quality have been conducted in high input large-scale production systems. However, the different pre-slaughter handling procedures that affect meat eating quality and consumer health also need to be evaluated in low input production systems. The objective of the current study was, therefore, to determine the effects of transportation time, distance, stocking density, temperature and lairage time on incidences of PSE and the physico-chemical characteristics of pork from low input production systems that were slaughtered at a low throughput abattoir.

2. Materials and methods

2.1. Description of study site

The study was conducted at Adelaide Municipal Abattoir under Nxuba local municipality in the Amatole District Municipality. The slaughterhouse is located approximately 120 km west of the town of East London. It is approximately 740 m above sea level. It is located 33.30 °S latitude and 26.30 °E longitudes.

2.2. Data collection procedures

A total of 280 pigs (large white and landraces) were monitored through deliveries in 34 consignments that occurred in the mornings to the slaughterhouse. The slaughterhouse was visited on two consecutive days twice a month: on the first day, handling of pigs prior to slaughter (i.e., transportation time, distance from farm to abattoir, stocking density, lairage duration and day temperature) were recorded (Table 1). On the second day meat pH_u and colour were measured at 24 h *post-mortem*. Samples for tenderness and cooking loss determination were also taken at 24 h *post mortem*. The measurements were taken from the *Muscularis longissimuss thoracis et. lumborum* (LTL) muscle.

2.3. Determination of transportation time and distance from farm to abattoir

The drivers were interviewed through the aid of structured questionnaires in order to have an idea of the driving experience and when the journey started. Transportation time and unloading time was obtained by calculating the time between the beginning of the journey and arrival at the abattoir. Lairage duration was determined as the time between the time of arrival at the abattoir and the beginning of the slaughter process. Information about stocking density, the number of pigs per compartment, the number of dead pigs on arrival, the number of emergency slaughtering, and the size (length, width, height) of a lorry compartment, the type of springs, mechanical ventilation and bedding material were recorded. The means and ranges of various pre-slaughter variables are shown in Table 1.

Table 1
Means and ranges of pre-slaughter variables.

Parameter	Mean ± SE	Range
Transportation time (h)	2.2 ± 0.49	1.5–3.7
Lairage (h)	1.1 ± 0.36	0.5–2.2
Stocking density(pigs/m^2)	0.4 ± 0.33	0.2–2.1
Distance (km)	56.1 ± 1.18	53–62
Day temperature (°C)	26.8 ± 5.58	13–39

2.4. Meat pH, temperature and colour determination

The pH_u and temperature measurements were performed 24 h after slaughter on carcasses from Landrace and Large White using a pH meter (Crison pH 25, Crison instruments, S.A., Alella, Spain). The pH meter was calibrated with pH 4 and pH 7 standard solutions. Carcasses with pH_u between 5.5 and 5.8 were classified into normal pork quality (i.e., red, firm and nonexudative (RFN)). Lower than 5.5 were classified into pale soft exudative pork (PSE). Higher than 5.8 were classified as dark firm dry (DFD) pork (Kortz, 2001; Nanni Costa et al., 1999). The carcasses were identified in slaughter sequence for temperature sampling (T_{24}) and pH_u. Both measurements were done on the *Longissimus dorsi muscle* (central area of the loin) on the right side of the carcass, at the level of the tenth and eleventh ribs.

Colour of the meat (L^* = Lightness, a^* = Redness and b^* = Yellowness) was also determined 24 h after slaughter using a Minolta colour-guide 45/0 BYK-Gardener GmbH machine, with a 20 mm diameter measurement area and illuminant D65-day light, 10° observation angle. Three readings were taken by rotating the Colour Guide 90° between each measurement, in order to obtain a representative average value of the colour. The guide was calibrated before each day's measurements using the green standard.

2.5. Thawing loss, cooking loss and evaporation loss determination

Percentage thawing loss, cooking loss and evaporation loss were calculated as follows: Immediately after slaughter before freezing, the samples from *Longissimus dorsi* were weighed. The samples were thawed over a period of 24 h at 0–4 °C and weighed again.

- Thawing loss = [(weight before thaw − weight after thaw) ÷ weight before thaw] × 100.
- Cooking loss = [(weight of raw steak after thawing − weight of cooked steak) ÷ weight of raw steak after thawing] × 100.
- Evaporation loss = 100 − [(weight after cooking) ÷ raw weight] × 100

2.6. Warner Bratzler shear force determination

The samples to be used for shear force determination were vacuum packed and frozen directly. A day before preparation, meat samples were thawed over 24 h at 0–4 °C. The steaks were placed in plastic bags and cooked in a water bath at 85 °C for 45 min (Ding, Kou, Cao, & Wei, 2010). Raw and cooked weights were recorded. The tenderness of pork was determined using Instron (3344, Universal Testing cross head speed at 400 mm/min, one shear in the centre of each core). Following cooking, sub samples of specified core diameter were cored parallel to the grain of the meat. The samples were sheared perpendicular to the fibre direction using a Warner Bratzler (WB) shear device mounted on an Instron 3344 (Universal Testing). The mean maximum load (N) was recorded for the batch.