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Technological quality attributes of pork from a smallholder abattoir as affected by breed, age and season of slaughter

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The objective of the current study was to determine the effect of breed, age group and season of slaughter on technological quality attributes of pork from a smallholder abattoir. Meat from the Large White pig meat had higher (P < 0.05) pH_u and lower a* than values of meat from the Landrace. No breed differences were observed in lightness (L*), yellowness (b*), shear force values, thawing loss, cooking loss and evaporation loss values. Meat from pigs slaughtered in spring season had the highest (P<0.05) shear force values (27.6 ± 1.58) while the lowest shear force values (18.5 ± 1.58) were found in meat from pigs that were slaughtered in autumn season. The lowest pH_u and highest a* values were found in meat from 9 months old pigs (5.3 ± 0.07). The 6, 9 and 10 months old pigs had higher (P<0.05) b* values than 7 and 8 months old pigs. Cooking loss and evaporation loss increased with age groups. The risks of PSE occurrences were more prevalent in autumn (37%) than other seasons of slaughter. Warner Bratzler Shear Force (WBSF), cooking loss (CL) and evaporation loss (EL) values increased with age of an animal. It was concluded that pH_u vary with pig breeds and considerations should also be made on different seasons of slaughter when assessing pork quality. Precautions should also be made on age categories of animal, the younger the animal. Less force is needed to shear it, low CL and EL point to good quality meat in young animals.

Key words: Ultimate pH, pork colour, tenderness, thawing loss, cooking loss, evaporation loss.

INTRODUCTION

Ante-mortem and *postmortem* factors and their interactions have considerable effects on meat quality. These factors have been observed to have profound effects on end-point meat pH (pH_u) and meat colour, Warner Bratzler Shear Force (WBSF) values, thawing loss, cooking loss and evaporation loss, which are considered to be the most important parameters of meat quality determination. Breed is one of the most important sources of variation in technological and sensory quality of pork (Mancini and Hunt, 2005; Edwards et al., 2003). Brewer et al. (2004) evaluated several sire lines (Duroc, Synthetic, Duroc/Landrace, Pietrain, Duroc / Hampshire, and Large White) and reported that genetic line affected loin chop two-toning, lightness, pinkness, and

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yellowness. Similarly, Edwards et al. (2003) reported that Duroc progeny had more favourable visual colour, higher pH, and increased redness than Pietrain sired pigs. Different breeds or lines may also vary in their stress reactivity (Terlouw, 2005). Pigs of similar genetic type (but of different genetic make-up) and kept in the same rearing unit (but having different social and other experiences) show different stress reactivity (Terlouw, 2005; Rosenvold and Andersen, 2005).

Season of slaughter has been shown to influence the welfare of pigs (Gosalvez et al., 2006). Extremes in summertime temperatures increased the risk of deaths on arrival (DOAs) and the risk of pale soft exudative meat (PSE) (Gregory, 2010; dalla Costa et al., 2007). Cold temperatures and poor vehicle design increase the incidence of bruised carcasses (dalla Costa et al., 2007). Therefore the time of year might be a medium stressor that acts independently from transport time (Maria et al., 2006). Hence, the seasonal temperatures are said to be the main reason for differences in meat quality (Kadim et al., 2008).

Increasing age of an animal at slaughter could result in reduction in pork quality. Indeed, meat quality of older culled animals differs from that of hogs. For instance, sow meat is considered more appropriate for processing some dry cured products. However, little information is available on whether the variation in age and weight at slaughter, within usual commercial limits, may influence muscle characteristics and sensory quality of pork. Simultaneous increase in age and weight of pigs may result in a lower sensory quality of pork, in spite of elevated intramuscular fat (IMF), possibly because of larger fibres and/or lower degree of post mortem proteolysis (Candek-Potokar, 1998).

The major components of cooking losses are thawing loss (TL), dripping loss (DL) and evaporation loss (EL) (Obuz et al., 2004; Jama et al., 2008). Thawing losses are lower following a rapid freezing compared with slow freezing because of small crystallization formed by the rapid freezing (Hui, 2004). Evaporation loss changes the shape of meat through shrinkage and causes firmness and poor juiciness (Yu et al., 2005). Jeremiah et al. (1999) reported that cooking loss and WBSF were reasonable indicators of sensory panel palatability within a breed. However, there is limited information concerning the effect of animal age, breed and season on the major components of cooking loss.

Most studies on improving meat eating quality have been conducted in big commercial abattoirs (high throughputs) under high input large-scale production systems. However, the effect of different pig breeds, age and season of slaughter on improving meat eating quality and consumer health also need to be evaluated in smallholder abattoirs (low throughputs) where most of the delivered animals for slaughter are from low input production systems. With Eastern Cape having 88 red meat abattoirs, 48 of them are smallholder abattoirs (low throughputs) supplying meat to the local butcheries and

consumers. Therefore, information on how age, breed and season of slaughter affect pork quality in low input systems will help local butcheries, farmers and consumers better understand the effects of these variables; thereby improving their productions systems and financial returns (profit). Hence, the objective of this study was to determine the effects of breed, age and season of slaughter on technological quality attributes of pork.

MATERIALS AND METHODS

Description of study site

The study was conducted at Adelaide Municipal Abattoir under Nxuba local municipality in the Amatole District Municipality. The area is approximately 740 m above sea level. It is located 33.30 °S latitude and 26.30 °E longitudes. Adelaide Municipal Abattoir is one of the small scale abattoirs (low throughputs) supplying meat to the local butcheries and consumers in the Eastern Cape province of South Africa.

Data collection procedures

A total of 280 pigs (Large White and Landraces) of mixed sex were monitored through deliveries in 34 consignments that occurred in the mornings to the slaughterhouse. The ages of the pigs were evenly distributed into the following age categories: 6, 7, 8, 9 and 10 months. The slaughterhouse was visited once a month and over four South African seasons (Summer: November, December and January; Autumn: February, March and April; Winter: May, June and July; Spring: August, September and October. Ultimate pH and colour were measured on carcasses at 24 h *post-mortem*. Samples for meat tenderness and cooking loss determination were also taken at 24 h *post mortem*. The meat samples were taken from the *Muscularis longissimuss thoracis et. lumborum* (LTL) muscle.

Carcass pH, temperature and colour determination

The pHu 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_{24} between 5.5 and 5.8 were classified into normal pork quality (that is, red, firm and nonexudative (RFN)). Carcasses with ultimate pH_{24} lower than 5.5 were classified into pale soft exudative pork (PSE) while those with pH_{24} higher than 5.8 were classified as dark firm dry (DFD) pork (Nanni Costa et al., 1999; Kortz, 2001). The carcasses were identified in slaughter sequence for temperature sampling (T_{24}) and pH_{24}. 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, 10º observation angle. Three readings were taken by rotating the Colour Guide 90º 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.

Thawing loss, cooking loss and evaporation loss determination

Percentage thawing loss, cooking loss and evaporation loss were determined as follows: Immediately after slaughter before freezing, samples from *Longissimus dorsi* muscle were obtained and weighed. The samples were thawed over a period of 24 h at 0 to 4°C and weighed again. Thawed steaks were placed in plastic bags and cooked in a water bath at 85°C for 45 min (Ding et al., 2010). Raw and cooked weights were recorded.

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

Warner bratzler shear force determination

The meat samples (approximately 100 g/carcass) to be used for shear force determination were obtained 24 h after slaughter and vacuum packed, frozen directly and stored for WBSF determination. A day before preparation, meat samples were thawed over 24 h at 0 to 4°C. The steaks were placed in plastic bags and cooked in a water bath at 85°C for 45 min (Ding et al., 2010). 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.

Statistical analysis

The PROC GLM procedure of statistical Analysis Systems (SAS) Institute (2003) was used to analyse the effect of breed, age and season and their interactions on colour (L*,a*,b*), pHu, cooking loss (CL), thawing loss (TL) and evaporation loss (EL). The model used was as follows:

$$Y_{ijkl} = \mu + B_i + A_j + S_k + E_{ijkl}$$

Where Y_{ijkl} = response variable (pHu, L*, a*, b*, CL, TL, EL)

μ = constant mean common to all observations
B_i = effect of breed
A_j = effect of age group (6, 7, 8, 9 and 10 month-old pigs)
S_k = effect of season
E_{ijkl} = random error

Comparisons of means were analyzed by least significance difference (LSD, SAS, 2003). Breed, age and season interactions were not significant in the initial analysis and hence were not included in the model. The association between pHu and season of slaughter was determined using the Chi-square test for association.

RESULTS

Effect of breed on technological properties of pork

Table 1 shows the effects of breed on various technological meat quality attributes. Meat from the large White had significantly higher pH_u and CL% values than

Table 1. Effects of different breeds on technological meat quality attribute.

Parameter	Landrace	Large white	Significance
pH_u	5.5 ± 0.21	5.7 ± 0.78	**
L*	48.7 ± 0.46	50.1 ± 1.71	NS
a*	7.7 ± 0.19	6.03 ± 0.68	*
b*	10.4 ± 0.19	10.1 ± 0.74	NS
WBSF	24.3 ± 0.64	21.2 ± 2.37	NS
TL (%)	11.0 ± 0.56	8.1 ± 2.08	NS
CL (%)	30.1 ± 1.14	34.1 ± 4.25	NS
EL (%)	37.5 ± 1.14	39.4 ± 4.24	NS

*P < 0.05; ** P < 0.01; NS: not significant.

meat from the Landrace while meat from the Landrace had higher values for redness (a*) and WBSF than meat from the Large White. No breed differences were observed in the L*, b*, thawing loss and evaporation loss. No interactive effects of breed, season and age on different technological attributes were observed.

Effect of season on technological properties of pork

Table 2 shows the effects of season on various technological meat quality attributes of pork. Meat from pigs slaughtered in spring had the highest pH_u values. Lowest pH_u values were observed in meat from pigs slaughtered during the autumn season. However, there were no significant seasonal differences in the L*, a*, b* values of pork. Meat from the pigs slaughtered in spring season had the highest (P<0.05) WBSF values and the lowest WBSF values were observed in meat from the pigs that were slaughtered in autumn.

Effect of age on technological properties of pork

The effects of age on various technological meat quality attributes of pork are shown on Table 3. Meat from 9 month-old pigs had the lowest pH_u values, whilst meat from 10 month-old pigs had the highest pH_u values. No significant differences were found in L* values of different age categories. Means for a* values for 6, 7, 8 and 10 months old pigs were not significantly different from each other. Meat from 9 month-old pigs had the highest a* values, while meat from 8 month-old pigs had the lowest values. The 6, 9 and 10 months old pigs had higher b* values (P < 0.05) than 7 and 8 months old pigs. Higher WBSF values were observed in pigs slaughtered between 6, 9, and 10 months old then 7 and 8 months old pigs. There were no differences in shear force values between 7 and 8 months old pigs although lower shear force values were observed in 7 months old pigs. Lower

Table 2. Effects of different seasons on technological quality attribute.

Parameter	Autumn	Spring	Summer	Winter
pH_u	5.4 ± 0.05^a	5.8 ± 0.05^b	5.6 ± 0.06^b	5.6 ± 0.05^b
L*	48.7 ± 1.16	49.6 ± 1.14	50.2 ± 1.27	49.1 ± 1.20
a*	6.8 ± 0.47^a	6.6 ± 0.46^a	6.1 ± 0.51^a	8.0 ± 0.48^b
b*	9.8 ± 0.50^a	10.5 ± 0.49^{ab}	9.2 ± 0.55^a	11.6 ± 0.52^b
WBSF	18.5 ± 1.61^a	27.6 ± 1.58^c	21.5 ± 1.76^a	23.3 ± 1.66^b
TL (%)	13.7 ± 1.41^c	9.5 ± 1.39^b	9.6 ± 1.55^b	6.1 ± 1.46^a
CL (%)	30.1 ± 2.87	35.6 ± 2.82	34.2 ± 3.14	28.7 ± 2.96
EL (%)	38.6 ± 2.87^b	42.2 ± 2.83^b	40.2 ± 3.15^b	32.9 ± 2.97^a

[a,b,c] Differences between the means of treatment groups carrying various letters in the same row are significant (*$P < 0.05$). Seasonal division is as follows: Summer: November, December and January; Autumn: February, March and April; Winter: May, June and July; Spring: August, September and October.

Table 3. Effects of different age categories on technological quality attribute.

Parameter	6 months	7 months	8 months	9 months	10 months
pH_u	5.5 ± 0.07^a	5.7 ± 0.05^b	5.5 ± 0.05^a	5.3 ± 0.07^a	5.8 ± 0.05^b
L*	50.1 ± 1.58	49.1 ± 1.03	49.8 ± 1.18	48.3 ± 1.44	49.7 ± 1.13
a*	7.0 ± 0.63^a	6.6 ± 0.41^a	6.1 ± 0.47^a	8.0 ± 0.58^b	6.7 ± 0.45^a
b*	10.7 ± 0.68^{ab}	9.4 ± 0.44^a	9.2 ± 0.51^a	11.0 ± 0.63^b	11.0 ± 0.48^b
WBSF	17.8 ± 2.18^a	25.3 ± 1.42^b	21.3 ± 1.63^{ab}	24.4 ± 1.99^b	25.0 ± 1.56^b
TL (%)	10.6 ± 1.91	9.9 ± 1.28	9.3 ± 1.43	10.1 ± 1.75	8.7 ± 1.37
CL (%)	21.0 ± 3.87^a	35.3 ± 2.53^b	36.8 ± 2.90^b	34.9 ± 3.55^b	32.7 ± 2.78^b
EL (%)	29.0 ± 3.88^a	41.7 ± 2.54^b	40.9 ± 2.91^b	41.4 ± 3.57^b	39.3 ± 2.79^b

[a,b,c] Differences between the means of treatment groups carrying various letters in the same row are significant (*$P < 0.05$).

($P<0.05$) cooking loss and evaporation loss were observed in 6 months old pigs than 7, 8, 9 and 10 months old pigs.

Chi square test for association between seasons and pH_u classes

On a pH_u classes of 5.5 to 5.8 (with pH >5.8 high representing occurrences of DFD cuts and pH <5.5 low representing occurrences of PSE meat), an association between seasons and pH_u classes was observed (Table 4). Highest ($P<0.001$) incidences of PSE carcasses were associated with autumn season. The association for the spring, summer and winter seasons of slaughter and pHu classes was poor ($P<0.01$), more carcasses were associated with pH 5.5 to 5.8 normal meat cuts. In total, 70 carcasses were associated with PSE, 65 carcasses were associated normal meat cuts and 23 carcasses had DFD problems.

DISCUSSION

The pH_u is determined by the extent of the pH decline at 24 h after slaughter. The variation in pH_u influences the factors such as meat colour and the ability of meat to retain water. In this study the lower ultimate pH (pH_u) values were reported in Landrace than in Large White, even though they were within the normal pH range for pork. The differences in pH values between Large White and Landrace are most likely to be due to difference in genetic make-up. Stress, prior to slaughter, is said to be one of the most important influences on pH_u and ultimate meat tenderness (Muchenje et al., 2009a). It may result from transportation, rough handling, inclement temperatures, or anything that causes the animal to draw on its glycogen reserves before slaughter (Muchenje et al., 2009b).

Meat colour is an extremely important parameter for judgement of the freshness and quality of meat (Martinez-Cerezo et al., 2005; Mancini and Hunt, 2005). Differences in meat colour observed in the current study can be attributed to breed and age variations in intramuscular fat and moisture contents as reported in other studies (Lambooij, 2000). Increased a* is often attributed to genotype effects on increased drip loss and oxymyoglobin concentration (Fabrega et al., 2002). The absence of breed effects on L*, b*, WBSF, TL, concurs with reports by Rosenvold and Andersen (2005) who observed no significant effects on lightness or redness of

Table 4. Chi square test for association between seasons and pH$_u$ classes.

Parameter	pH >5.8 high (DFD)	pH 5.5-5.8 normal	pH <5.5 low (PSE)	Total
Autumn	2	15	37	54
Spring	11	23	11	45
Summer	2	14	12	28
Winter	8	13	10	31
Total	23	65	70	158

Seasonal divisions are as follows: Summer: November, December and January; Autumn: February, March and April; Winter: May, June and July; Spring: August, September and October.

meat from different breeds. Similarly, Cassens (2006) found no breed effects on colour. The presence of the halothane allele (Nn or nn; Channon et al., 2000) detrimentally affects pork colour (increased paleness) and protein denaturation (increased transmittance; Piedrafita et al., 2001).

Season had a significant influence on pH$_u$, with low pH$_u$ reported in autumn season than other seasons. The high incidence of pork with low pH$_u$ registered in this study is indicative of the effects of environmental factors which should hence be taken into account whenever the effects of seasonal conditions on pork quality are evaluated (dalla Costa et al., 2007). In the current study, the observed high percentages of carcasses with the incidence of PSE were reported on pigs slaughtered during autumn (37%) and can be attributed to the variations in environmental conditions with seasons (Guardia et al., 2004). The effects of temperature; humidity; draught; weather (e.g. snow, rain, sun) have been shown to be important when assessing the potential welfare risks to animals during road transport (Nielsen et al., 2010). Guardia et al. (2004) reported that PSE prevalence is expected to be higher in summer than other seasons while Maria et al. (2006) observed low prevalence of PSE in winter. Guise and Penny (1989) reported that when pigs are kept in environments with low temperatures, they group together to reduce heat loss. However, huddling behaviour reduces the space allowance leading pigs to fight or climb over the backs of other pen- mates to seek a place to rest, hence the higher incidence of pork with lower pH$_u$ in winter (Nielsen et al., 2010).

Season affected the WBSF values, with lowest WBSF values recorded in autumn (18.5) and highest WBSF values reported in spring (27.6) season. Our findings suggest that WBSF values might be a consequence of the low pH$_u$ registered in autumn. Muchenje et al. (2008) reported no significant relationship between meat tenderness and pH, although Byrne et al. (2000), Strydom et al. (2000) and Vestergaard et al. (2000) showed that meat tenderness is related to ultimate pH

(pH$_u$) value and meat colour. Warner–Bratzler shear force is accepted as a good predictor of tenderness observed sensorially and could be used as a criterion to determine meat acceptability (Sanudo et al., 2003). Meat tenderness and texture are important factors for consumers since they determine the commercial value of the meat and the way it will be cooked (Lepetit and Culioli, 1994).

Season of slaughter had a significant influence on the major components of cooking loss, thawing loss and evaporative loss. The differences in cooking and thawing losses in the current study and those reported by other authors may be attributed to several factors such as differences in ageing, cooking method applied, cooking temperatures, duration of cooking temperatures, pH and Marbling (Jama et al., 2008; Yu et al., 2005).

The observed effects of age on pH$_u$ can be attributed to the fact that an animal's behaviour differs with an animal's age and the stage of growth (Terlouw et al., 2009). The lower pH$_u$ values measured in younger pigs (6 and 8 months) and older pigs (9 months) might reflect higher glycogen usage during the pre-slaughtering phases. Meat from 9 months old pigs showed high a* values compared to all age categories (6, 7, 8 and 10 months) having light meat than 9 months. These results are most likely to be due to the different state and concentrations of myoglobin of different ages.

Age at slaughter significantly affected the WBSF values, with low WBSF values reported in 6 month-old pigs than the older pigs suggested that WBSF values increases with an age of an animal. Sources of tenderness variation in beef for instance may be attributed to animal's age, sex, liveweight; breed and ante-mortem stress (Muchenje et al., 2009a). Meat tenderness is a function of the collagen content, heat stability and the myofibrillar structure of muscle (Muir et al., 2000), and these appear to be affected mainly by the rate of growth of the animal rather than the breed *per se* (Muchenje et al., 2009a). In the current study, total CL and EL increased with age suggesting increased denaturation of protein with age, or increased cross-linking of collagen with age, resulting in decreased water-holding capacity with increased moisture loss upon heating or cooking (Schonfeldt and Strydom, 2011). Therefore, the ability of the muscle to retain water decreases with increased age leading in higher cooking losses in cuts from older animals, with an associated drier end-product, without the rapid release of meat fluid during the first few chews as found in meat from young animals (Schonfeldt and Strydom, 2011).

Conclusion

It can be concluded that pig breeds vary in pH$_u$ and considerations should be made on different seasons of slaughter when assessing pork quality. Precautions

should also be made on age categories on an animal, the younger the animal, the less force is needed to shear it, low CL and EL and therefore good quality meat.

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