

A survey on the effect of transport method on bruises, pH and colour of meat from cattle slaughtered at a South African commercial abattoir

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Abstract

In this study the effect of transport method on bruising, ultimate pH (pH_u) and colour of beef (L^* = lightness, a^* = redness and b^* = yellowness) was determined. Cattle transported directly from farms had the highest bruise scores, pH_u and the lowest L^* values. There were significant correlations between pH_u and L^* , a^* and b^* values, ($r = -0.45$, $r = -0.59$ and -0.55 , respectively), pH_u and bruise score ($r = 0.34$), and L^* and bruise score ($r = -0.24$). There were positive relationships between transport distance and pH_u and between distance and bruise score, while the relationship between L^* and distance was negative. Percentage of bruised carcasses varied with method of transport: Group 1, 41.1%; Group 2, 63.1% and Group 3, 51.1%. Transport method affected bruising, pH_u and colour of beef.

Keywords: Bruise score, ultimate pH, DFD meat, animal welfare, pre-slaughter stress

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Introduction

The meat supply chain is an important aspect in the farming and meat industry that includes various critical stages such as transportation, loading and slaughter of the animals (Ali *et al.*, 2006; Ljunberg *et al.*, 2007; Tadich *et al.*, 2009). Furthermore, many farmers have developed intermediate stages in the chain, thus making the process dynamic and often complicated. In South Africa, cattle are marketed through a number of channels, with selling through butchereries, auctions and abattoirs playing a leading role (Museumwa *et al.*, 2007). The use of auction markets, holding farms or feedlots often exposes the animals to stressful conditions and a breach to animal welfare (Ferguson & Warner, 2008), often resulting in bruises (Strappini *et al.*, 2010).

Transportation of animals may vary depending on the source of the animals and in South Africa, cattle that are sold at auction markets can either be transported straight to the slaughterhouse for direct slaughter or can be taken to farms or feedlots where they are held before released for slaughter (Coetzee *et al.*, 2004; Museumwa *et al.*, 2008). The various transportation methods imparts different degrees of bruising, and findings by Weeks *et al.* (2002) showed higher bruises in cattle sourced directly from the auction markets than in cattle sourced directly from the farm. Contrary to these reports, Ljunberg *et al.* (2007) reported no significant differences between the bruise scores of animals slaughtered after transport direct from farms and those from livestock markets, although bruise distribution was different.

Bruised cattle are stressed and are expected to produce an abnormally high pH in the muscle because of glycogen depletion and the subsequent lower production of lactic acid in the muscles (Kannan *et al.*, 2002). A high pH favours the development of dark, firm, dry (DFD) beef and a reduction of shelf life of meat (Chambers *et al.*, 2004). Beef with an ultimate pH (pH_u) of above 6.0 presents many quality problems such as dark red colour, toughness, increased water holding capacity and poor palatability (Apple *et al.*, 2005; Mounier *et al.*, 2006; Muchenje *et al.*, 2009a).

Most studies tend to focus on stress (Ndlovu *et al.*, 2009; Odore *et al.*, 2011) and meat quality (Muchenje *et al.*, 2008; 2009b) separately, yet the way an animal is handled before slaughter is likely to affect the quality of the meat (Muchenje *et al.*, 2009a). Furthermore, information on animal stress and how it affects meat quality under practical situations, especially in low throughput abattoirs which have low levels of mechanisation, is generally lacking. Such lack of information is more pronounced when considering animals marketed and transported through different methods to the abattoirs in rural communities. Also limited, is the use of bruise ageing to predict the time of occurrence of bruises and the relationship between bruised carcasses and the development of pH, colour and DFD beef. This, despite the fact that information on animal welfare and meat quality is quite critical for veterinarians and the animal/meat industry. The objective of the study was therefore to determine carcass bruising at the abattoir, beef colour and pH_u. The study also sought to quantify the relationship between bruising, colour and pH_u with animal characteristics, seasonal conditions, marketing channel and mode of transportation.

Materials and Methods

The study was conducted at the Adelaide municipal abattoir (32.8 °S and 26.9 °E) in the rural town of Adelaide (Nxuba Local Municipality), Amatole District Municipality in the Eastern Cape Province of South Africa. The abattoir is classified as low throughput. The day temperature range for the period of study was from 8 °C to a high of 35 °C with a mean temperature of 21.5 °C. The average daily temperatures during transportation were obtained from the Adelaide town weather records.

Data were collected from 315 cattle that were divided into three groups depending on their marketing history and mode of transport to the abattoir. Group 1 was walked to the abattoir from feedlots or holding farms close to the abattoir, Group 2 was transported by road from various farms to auction markets and then directly to the abattoir while Group 3 was transported by road directly from the farms to the abattoir.

Truck identification, the number of animals loaded on the truck, the stocking density in the truck and the transportation distances were recorded for Groups 2 and 3. For Group 1, transportation distance was obtained by herding the cattle on routes where the distances were predetermined.

Data on animal source (farm, feedlot or auction market), breed and sex were recorded on arrival at the abattoir. The cattle were slaughtered directly upon arrival. Slaughtering was done through stunning by captive bolt, suspension by a hind leg and exsanguination. Meat inspection and classification were done by a qualified meat inspector.

Bruise score assessment was done using a method based on the Australian Carcass Bruise Score System (Anderson & Horder, 1979). After dressing, the carcasses were examined and the size and colour of every bruise were recorded. The maximum diameter was estimated as: little (<2 cm), slight (2 - 8 cm), medium (8 - 16 cm) or heavy (>16 cm). Bruise scores were calculated for each load by multiplying the number of bruises in each size class by a weighting factor: slight 1, medium 3 and heavy 5, and adding these values (Anderson & Horder, 1979). These bruise scores were then divided by the number of cattle per load to give a mean bruise score per animal for each load.

Bruise age was estimated using the method of Gracey *et al.* (1999) as described in Table 1.

Table 1 Colour observations used to estimate the age of bruises

Observable colour of the bruise	Estimated age of the bruise in hours
Red and haemorrhagic (bright-red)	0 - 10 hours old
Dark-red colour	11 - 24 hours old
Watery consistency	25 - 38 hours old
Rusty orange colour, soapy to touch, clear yellow mucus	39 - +72 hours (3 days old)

Gracey *et al.* (1999).

Measurement of pH was done in the *longissimus dorsi* muscle at the level of the 10th rib, approximately 24 hours after slaughter, of carcasses that were refrigerated at 0 – 3 °C. The measurement was

carried out using a portable pH meter (CRISON pH25, CRISON Instruments SA, Spain) that was calibrated using pH 4, pH 7 and pH 9 standard solutions (CRISON Instruments, SA, Spain) before each day's measurement. The carcasses were classified as normal when the pH was <6 , or as DFD beef at a pH of ≥ 6 (Muchenje *et al.*, 2009a).

Colour of the meat (L^* = lightness, a^* = redness and b^* = yellowness) was determined in the *longissimus dorsi* 24 hours after slaughter, using a colour-guide 45/0 BYK-Gardener GmbH machine, with a 20 mm diameter measurement area and illuminant D65-day light, 10 standard observer. 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.

The effect of transport method on bruises, pH and colour was analysed using the General Linear Model (PROC GLM; SAS, 2003). The proportion of carcasses with potentially DFD beef and the prevalence of bruises by transport method were determined using the frequency procedure (PROC FREQ; SAS, 2003). Significant differences between least-square group means were analysed using the PDIF procedure of SAS (2003). A regression analysis was done to determine the relationship of varying distances, stocking density (Groups 2 and 3) and day temperature on bruise score, bruise age, pH_{24} and colour (PROC REG; SAS, 2003), while correlations were done for the relationship between transport method and other meat quality related data and between pH and colour (PROC CORR; SAS, 2003).

Results and Discussion

Meat quality variables that were affected by transport method are presented in Table 2. A total of 315 cattle passed through the abattoir during the survey period; 158 were in Group 1, 65 in Group 2 and 92 in Group 3. Cattle received on hoof constituted the highest number that passed through the abattoir during the study period.

The bruised and non-bruised carcasses in each group are shown in (Table 2). Percentage of bruised carcasses varied with method of transport: Group 1, 41.1%; Group 2, 63.1% and Group 3, 51.1%, but the actual bruise scores reflected a different pattern.

Table 2 Meat quality measurements per transportation group

Meat quality variables	Group 1	Group 2	Group 3
$pH_{24} \geq 6$	65 (41.1)	41 (63.1)	47 (51.1)
$pH_{24} < 6$	93 (58.9)	24 (36.9)	45 (48.9)
Colour			
≤ 33	65 (41.1)	41 (63.1)	47 (51.1)
> 33	93 (58.9)	24 (36.9)	45 (48.9)
Bruising			
Bruised (%)	65 (41.1)	41 (63.1)	47 (51.1)
Non- bruised (%)	93 (58.9)	24 (36.9)	45 (48.9)

Figures in brackets indicate % of each variable per group.

Group 1: Received on hoof from feedlots/holding farms;

Group 2: Transported by road from various farms to auction markets and then directly to the abattoir;

Group 3: Transported by road from the farms directly to the abattoir.

The bruise scores were significantly higher in carcasses in Groups 2 and 3 than in Group 1 (Table 3) and there was no significant difference in bruise scores between Groups 2 and 3 carcasses. This is in accordance with Ljunberg *et al.* (2007) who found no significant differences in bruise scores between farm and auction marketed cattle. The percentage of bruising for Group 1 cattle reflects their marketing history. These cattle were transported by road from different farms to the markets where the meat traders purchased them and then transported them by road again to holding farms. Since auction markets are held monthly and

the purchased cattle are only slaughtered when there is demand, the cattle were kept for various periods of time before they were slaughtered. Although Group 2 cattle had the highest percentage of bruised carcasses, as expected, and in agreement with the findings by Weeks *et al.* (2002) and Strappini *et al.* (2010), Group 3 carcasses actually had the highest bruise scores. This can be explained by the possible modifying effect of transportation distance.

Table 3 Least square means and standard error of means of bruise score, ultimate pH (pH_u) and colour from the three different transportation methods

Group	Meat quality variables		
	Bruise score	pH _u	Lightness (L*)
1	6.45 ± 0.79 ^b	5.77 ± 0.04 ^b	37.50 ± 0.78 ^a
2	8.60 ± 1.06 ^a	5.78 ± 0.05 ^b	38.16 ± 0.99 ^a
3	10.70 ± 1.05 ^a	5.90 ± 0.05 ^a	35.93 ± 0.97 ^b

^{ab} Means in the same column with different superscripts are significantly different at $P < 0.05$.

Group 1: Received on hoof from feedlots/holding farms;

Group 2: Transported by road from various farms to auction markets and then directly to the abattoir;

Group 3: Transported by road from the farms directly to the abattoir.

Distance was found to have a significant and positive effect on bruise score (Table 4). In this study cattle from farms were transported over longer distances compared to cattle from the auction markets. The fact that distance had a positive relationship with bruise score might explain the high bruise scores in cattle that came directly from farms. According to Hoffman *et al.* (1998), distance is positively correlated with amount of bruising.

Table 4 Relationship between transportation variables and bruise score, pH_u, L*, and bruise age

Parameter	Variable	Relationship	Regression equation	Significance
Bruise score	Distance	Linear	$Y = 7.16(0.422) + 0.05(0.007) X$	*
	Stocking density	Linear	$Y = 9.44(1.126) + 0.26(0.214) X$	*
pH _u	Day temperature	NS		NS
	Distance	Linear	$Y = 5.80(0.020) + 0.001(0.002) X$	*
	Stocking density	Linear	$Y = 5.80(0.040) + 0.021(0.008) X$	*
L*	Day temperature	NS		NS
	Distance	Linear	$Y = 36.98(0.375) - 0.023(0.006) X$	*
	Stocking density	Linear	$Y = 37.03(0.787) - 0.30(0.150) X$	*
Bruise age	Day temperature	NS		NS
	Transport time	Linear	$Y = 2.99(0.382) + 0.169(0.075) X$	*

*Significant at $P < 0.05$; Values in parentheses show the standard error; NS – not significant.

pH_u: ultimate pH; L*: lightness (colour of the meat).

The evaluation of bruise age reflected an interesting pattern. Group 1 carcasses had the oldest bruises, (92.4% was older than 10 hours), and this group also had the greatest number of dark and yellowish bruises, thus reflecting the history of the animals. The age of the majority of bruises in Groups 2 and 3 aged was less than 10 hours (66% and 72%, respectively) (Table 5).

Table 5 Distribution of bruise age by method of transport

Bruise age	Group 1	Group 2	Group 3
	%	%	%
<10 hours	7.7	65.6	72.3
10 - 24 hours	29.3	31.7	27.7
24 - 38 hours	30.8	2.4	0
+ 72 hours	32.3	0	0

Group 1: Received on hoof from feedlots/holding farms;

Group 2: Transported by road from various farms to auction markets and then directly to the abattoir;

Group3: Transported by road from the farms directly to the abattoir.

The findings for the three groups are in agreement with that of Gracey *et al.* (1999). Bruise age is dependent on time between occurrence of the injury and the time of assessment. In this study, bruise age had a significant and positive relationship with duration of transportation (Table 4). Although interpretation of bruise age based only on visual assessment is not precise, bruise age was found to be significantly related with duration of transportation in this study. It must, however, be acknowledged that assessing bruise age using bruise colour changes is not a reliable method. The limitation of this method lies in the difficulty of accurately separating bright red bruises from dark red bruises. This is entirely due to ageing of the bruise as the difference in colour can be affected by the contribution of venous blood or arterial blood at the site. Another limitation of the method is that observation of a watery bruise can be due to oedema rather than ageing of the bruise.

Meat pH₂₄ was greater than or equal to 6.0 for 41.1% of Group 1, 63.1% of Group 2 and 51.1% of Group 3 carcasses (Table 2). Similar results were also found for L* ≤ 33 and in both cases the carcasses were classified as DFD beef. There was also a significant positive correlation between pH_u and bruises (Table 6).

Table 6 Correlations among ultimate pH, colour (L*, a*, b*), bruise score and carcass weight

pH	L*	Bruise score	a*	b*
pH ₂₄	-0.454 ***	0.339 ***	-0.594 ***	-0.554 ***
L*		-0.237 ***	0.021 NS	-0.047 NS
Bruise score			0.218 NS	0.069 NS
Carcass weight				-0.005 NS

*** P < 0.05, NS - not significant.

Colour of the meat: L*: lightness; a*: redness; b*: yellowness.

These findings show a relationship between bruising and DFD beef and concur with McNally & Warriss (1996) who reported 48% of bruised carcasses having pH_u values greater than 5.8. The presence of bruises is a reflection of transportation problems and when animals are stressed, glycogen reserves are depleted and higher pH can be obtained (Muchenje *et al.*, 2009a; b). The relationship between the pH_u and DFD beef is also supported by the colour values obtained in the three groups (Table 2). Beef L^* values less than 33 indicate beef that is dark and translates to DFD beef (Muchenje *et al.*, 2008). While the above statements can be true for Groups 2 and 3, Group 1 cattle received a different treatment prior to slaughter. These cattle may have been stressed by the way they were herded to the abattoir. Walking cattle alone without food and water can be stressful, leading to glycogen depletion and high pH_u and low L^* values. Group 3 carcasses had significantly higher pH_{24} values and significantly lower L^* than both Group 2 and Group 1.

Other factors can have a significant affect on meat quality in terms of colour and pH_u . Method of transport affected pH_u and L^* (Table 5). Although there was a significant positive linear relationship between distance and pH_u , the pH values obtained could have been due to other factors than distance, since moderate transportation distances do not have an effect on pH_u (Mach *et al.*, 2008; Odore *et al.*, 2011). Factors that could have negatively affected carcass pH and hence colour include poor handling during loading and unloading (slip and fall), lack of water and food at the market and poor handling during transportation. From the regression analysis, a significant positive linear effect of distance, stocking density and transportation duration on pH_u was observed, while a significant negative linear effect of distance, stocking density and transportation duration was observed on L^* (Table 5). The positive linear relationship between stocking density and amount of bruising explains the increase in bruising that occurred with increasing stocking density. According to Gregory (2008), bruising increases with increase in stocking density because cattle that fall down tend to be trampled by others as they try to occupy the available space. Significant correlations were found between pH_u and L^* (negative), pH_u and bruise score (positive), L^* and bruise score (negative).

Other variables studied such as day temperature did not have an effect on meat quality. in accordance to Strappini *et al.* (2010).

Conclusion

Method of transport had an effect on bruising, beef colour and ultimate pH. Bruising was more prevalent in cattle that passed through the markets. Increased stocking density, distance and transportation duration had negative effects on cattle welfare and the quality of beef. Bruising was associated with increased carcass pH and the development of DFD beef.

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