Effect of slaughter age and breed on the carcass traits and meat quality of beef steers finished on natural pastures in the arid subtropics of South Africa

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Abstract

Simmentaler cross (SX), Bonsmara cross (BX) and Nguni (NG) steers were raised on natural sweet veld pastures and slaughtered at 18 or 30 months of age. Slaughtering occurred at the end of the wet summer season. Live weight and carcass traits were significantly influenced by breed and slaughter age. The amount as well as percentage kidney and omental fat differed significantly between the respective slaughtering ages, but only between breeds at 30 months of age. Breed and slaughter age affected back-fat thickness. All fat parameters were lower at 18 months than at 30 months of age. Breed did not have a large influence on meat quality attributes, but age did. Drip loss was similar for the breeds and slaughter age groups. The meat was darker and more red at 30 months than at 18 months of age. The pH_{24} of the _longissimus_ muscle was 5.51 and 5.67 at 18 and 30 months of age, respectively. No breed differences were detected for sensory panel attributes or Warner-Bratzler shear force values. Sensory panel tenderness and Warner-Bratzler shear force values indicated tougher meat from 30-month old steers than from 18-month old steers. Differences in meat quality were probably due to the combined effects of fatness, pH and collagen characteristics. It is concluded that in sweet veld areas steers from small- to medium-framed breeds can be raised successfully and slaughtered at 30 months of age without supplementation of natural pastures. Slaughtering steers at younger ages may require supplementary feeding or feedlot finishing.

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Introduction

Beef is produced either intensively in feedlots, or semi-intensively or extensively from pastures. The dietary effect on carcass and meat quality of cattle has been researched intensively. Varying dietary energy levels (Prior _et al._, 1977; Loveday & Dikeman, 1980; Crouse _et al._, 1985a) as well as grain _vs._ forage based diets (Bowling _et al._, 1977; Young & Kauffman, 1978; Schroeder _et al._, 1980; Crouse _et al._, 1984; Fortin _et al._, 1985; Newsome _et al._, 1985; Bidner _et al._, 1986) or pasture _vs._ feedlot finishing (Schaake _et al._, 1993; Bennett _et al._, 1995; Camfield _et al._, 1999) and breed types/frame size (Koch _et al._, 1976; Cianzio _et al._, 1982; Tatum _et al._, 1986a; Tatum _et al._, 1990; Dolezal _et al._, 1993; Camfield 1997; Short _et al._, 1999) were the focus of various research studies abroad. In general, carcasses from feedlot-fed cattle are heavier and contain more fat than carcasses from forage-fed cattle. Beef from forage fed cattle is also darker and less tender than meat from feedlot-fed cattle. Most of these studies were conducted in the USA where consumers prefer heavier carcasses exhibiting a substantial degree of marbling. In South Africa consumers prefer lean meat with little visible fat. Here carcasses are produced to suit consumer preferences and are seldom trimmed of excess fat.

In South Africa research concerning the utilization of forage revolved around nutritional, reproductive and growth responses following supplementation on sour veld pastures (Erasmus & Barnard, 1985; Gertenbach & Van H. Henning, 1995a), and enhancing the nutritional value of planted pastures (Le Roux _et al._, 1999; Taute _et al._, 2002) as well as crop residues (Cloete & Kritzinger, 1985; Brand _et al._, 1989; Snyman & Joubert, 2002). Most carcass and meat quality related research revolved around feedlots (Meaker & Barnard, 1988; Casey _et al._, 1990; Swanepoel _et al._, 1990; Gertenbach & Van H. Henning, 1995b; Strydom _et al._, 2000; Strydom _et al._, 2001). At the Mara Research Station research on natural pastures (sweet veld) focused on cow production and efficiency (Venter, 1977; Van Zyl, 1990; Lademann, 1992; Meaker, 1993).

The possibility exists that beef produced from natural sweet pastures can, apart from meeting consumer expectations, also be classified as organically produced. This enables the producer to add value to his product by targeting this niche market. Marketing at 30 months of age will result in higher returns per animal as a much heavier carcass can be sold than at 18 months of age. The weight gained during this period will more than compensate for the lower price/kg that results from marketing older carcasses, especially if there is no substantial difference in the prices for the different carcass classes. However, no information is available on the effects of genotype and age of cattle kept under sweet veld grazing conditions on carcass characteristics.

The objectives of this study were to evaluate breed types suitable for finishing off on natural, sweet pastures as well as the influence of age at slaughter on their carcass and meat quality.

Materials and methods

The study was conducted from 1999 to 2003 on *ca.* 4 387 ha on the eastern side of the Mara Research Station (23° 05' S and 29° 25' E; 961 m.a.s.l). The Mara Research Station is situated in the Arid Sweet Bushveld (Acocks, 1988). The vegetation in the study area included the woody species *Acacia tortilis*, *Commiphora pyracanthoides*, *Boscia albitrunca* and *Grewia* spp. and the grass species *Eragrostis rigidior*, *Panicum maximum*, *Urochloa mosambicensis* and *Digitaria eriantha* (Dekker *et al.*, 2001). The long-term mean annual rainfall at the Mara Weather Station is 452 mm of which *ca.* 80% falls from November to March. The mean daily maximum temperature ranges from 22.6 °C in June to 30.4 °C in January. During the study period, the mean annual rainfall (measured from July to June) was 410 mm, ranging from 232 mm to 846 mm per annum.

In this investigation the productivity of three different breeds/frame sizes on sweet veld was evaluated. Simmentaler cross (SX), Bonsmara cross (BX) and Nguni (NG) steers representing large-, medium- and small-framed types, respectively, were used in this study. Animal origin and general animal husbandry practices were described in more detail by Du Plessis & Hoffman (2004).

Steers born during a specific calving season were randomly divided into three groups and slaughtered at two different ages, namely at 18 or 30 months of age. Steers born from October 1999 to December 2001 were slaughtered either in May 2002 or May 2003. Slaughtering coincided with the end of the wet summer season. The live weights (LW) of the steers were recorded at 28 day intervals after withholding food and water for at least 12 h. Live weights at 18 and 30 months of age (548 and 912 days of age respectively) were either interpolated or extrapolated from the 28 day weight records.

On the day of slaughter steers were transported for 35 km to the abattoir. Steers were slaughtered using standard South African techniques and conditions. Care was taken to ensure that all ante mortem factors were standardized as far as possible.

Carcasses were quartered 48 h *post-mortem*, whereafter all carcass measurements were recorded and sampling was conducted. Cold carcass weight (CCW) was also corrected for age. Dressing percentage (DP) was calculated as the proportion of the CCW of the LW. Carcass length was measured from the centre of the first rib to the centre of the pubic symphysis and used to calculate carcass compactness (kg/cm; Swanepoel *et al.*, 1990). Back-fat thickness (BFT) was measured at the 12th rib, *ca.* 5 cm from the dorsal midline. All kidney (KF) and omental fat (OF) were removed, weighed and expressed as a percentage of carcass weight.

The prime rib cuts (9th, 10th and 11th ribs) were removed from both sides of the carcasses. The *M. longissimus dorsi* (*longissimus* muscle) from the left rib cut was immediately dissected, labelled and kept at 4 °C until drip losses were determined later on the same day. Drip and cooking losses were determined according to the methods set out by Honikel (1998). Cooking losses (cooked for 1 hour at 80 °C) were determined 72 hours *post-mortem*. Cooked samples were cooled in running water at room temperature (~25 °C) prior to determining the final weight.

To determine Warner-Bratzler shear force (WBS) values, five 12.7 mm diameter cores were cut perpendicular to the longitudinal axis of the muscle fibres at a crosshead speed of 299 mm/min (Voisey, 1976) from the same samples used to determine cooking loss. The mean for the WBS-values of the five cores was calculated.

Colour measurements (average of three random measurements) were taken from the surface of freshly cut steaks after a 20 minute blooming period (Stevenson *et al.*, 1989) using a Color-guide 45°/0° colorimeter

(BYK-Gardener, USA) with scales for lightness (L*; 0 = black, 100 = white), redness (a*; + = red, - = green) and yellowness (b*; + = yellow, - = blue).

After trimming, the right side *longissimus* muscle was labelled, vacuum packed, frozen and stored at –18 °C until the sensory evaluations were made.

Sensory evaluations were conducted on the *longissimus* muscle of the prime rib cut (9th, 10th and 11th ribs) from the right side of the carcasses from steers slaughtered at 18 and 30 months of age in May 2003. As different age groups were slaughtered at intervals of 12 months, comparisons between groups slaughtered in different years could not be made. Before the sensory evaluation, the *longissimus* muscle samples were thawed for 24 h at a temperature of 2-4 °C. Meat samples were cut to a uniform size and placed on foil covered metal racks. Each metal rack was placed in a coded cooking bag and a probe inserted into the centre of the meat. The samples were roasted at 160 °C (Viljoen *et al*., 2001) to an internal temperature of 68 °C (American Meat Science Association, 1978). The meat was allowed to rest for 5 min, during which time an endpoint temperature of 72 °C was reached. Cubed samples (1.5 cm x 1.5 cm) were taken from the middle of each *longissimus* muscle sample and individually wrapped in aluminium foil. The samples were placed in preheated glass ramekins marked with random three-digit codes and placed in a preheated oven at 100 °C and evaluated within 10 min.

Descriptive sensory analyses were performed on the meat samples. Five panelists were selected and trained in accordance with the guidelines for the sensory evaluation of meat (American Meat Science Association, 1978). The meat samples were evaluated for the following sensory attributes: beef aroma intensity, initial impression of juiciness, sustained juiciness, tenderness, residue and overall beef flavour, by means of an eight-point structured scale. The meat was evaluated in 12 sessions, controlled for age per session. The panelists were seated in individual booths in a temperature and light-controlled room, receiving a set of three samples served in a complete randomized order.

Carcass and meat trait results were analyzed statistically with a univariate ANOVA using the GLM procedure. Breed and age at slaughter were included as the main effects. Least significant differences were determined between means. The experimental design of the sensory evaluation consisted of a randomized incomplete block design. The treatment design was a 3 x 2 factorial design with three breeds and two slaughter age groups as the main factors. Where appropriate, data were also pooled to test for the main effects of breed and slaughter age. Prior to analyses of variance, the sensory scores were transformed to ranks. Tukey's LSD was calculated at a 5% significance level to compare treatment means (SAS, 1990).

Results

Breed and slaughter age had an effect (P < 0.05) on live and carcass weight and carcass compactness of the beef steers (Table 1). Simmentaler crosses presented the highest (P < 0.05) values for the above parameters, with the lowest (P < 0.05) derived from NG. These parameters were also influenced (P < 0.05) by slaughter age. However, neither breed nor slaughter age had any influence (P < 0.05) on DP.

Both amount and proportion of KF presented an interaction (P < 0.05) between breed and slaughter age. At 30 months of age both the amount and percentage of KF were higher (P < 0.05) in NG (2709.3 ± 256.65 g and 1.3 ± 0.0133%, respectively) than in either SX (1706.9 ± 224.21 g and 0.71 ± 0.0876%, respectively) or BX (2101.9 ± 193.81 g and 0.95 ± 0.0678%, respectively), with no differences (P > 0.05) between breeds at 18 months of age. In BX and NG, KF was lower at 18 months of age (1255.1 ± 72.05 and 1082.6 ± 73.58 g, respectively) than at 30 months of age, whereas percentage KF was higher at 30 months of age than 18 months of age only in NG (0.81 ± 0.0504%).

Amount of OF was highest (P < 0.05) in NG (2896.1 ± 117.58 g) at 30 months of age, whereas SX (1614.7 ± 255.33 g) and BX (2343.2 ± 166.17 g) also differed (P < 0.05) from each other. In both BX and NG, OF was lower at 18 months of age (1520.5 and 1666.9 g, respectively) than at 30 months of age. However, OF as a proportion, was only influenced by breed (Table 1). Similar to BFT, the lowest (P < 0.05) values for percentage OF were found in SX, and the highest (P < 0.05) in NG (Table 1). Backfat thickness was also lower (P < 0.05) at 18 months than at 30 months of age.

The pH_{24} (Table 1) did not differ (P > 0.05) among the breed types, but was lower (P < 0.05) at 18 months of age than at 30 months of age. No significant differences among breed types or slaughter age were observed for drip and cooking losses. Whereas breed did not influence (P > 0.05) any of the colour

measurements, both L* were lower (P < 0.05), and a* values higher (P < 0.05), at 30 months of age, indicating meat with a darker and more red colour.

Table 1 Carcass, fat and meat characteristics (means ± s.e.) of beef steers finished on natural pastures in the arid subtropics of South Africa as influenced by breed and slaughter age

Parameter	Breed[#]			Slaughter age (Months)	
	SX	BX	NG	18	30
Live weight (kg)	$446.1^a \pm 22.50$	$378.8^b \pm 17.87$	$346.7^c \pm 11.53$	$309.2^b \pm 7.80$	$441.5^a \pm 9.81$
Carcass weight (kg)	$216.8^a \pm 12.11$	$182.3^b \pm 8.65$	$166.2^c \pm 5.99$	$148.9^b \pm 4.42$	$212.5^a \pm 5.18$
Dressing %	48.5 ± 0.75	48.5 ± 1.53	47.9 ± 0.40	48.3 ± 1.09	48.1 ± 0.42
Carcass compactness (kg/cm)	$0.85^a \pm 0.03$	$0.73^b \pm 0.02$	$0.71^c \pm 0.02$	$0.65^b \pm 0.01$	$0.83^a \pm 0.01$
Fat characteristics					
Kidney fat (g)	1399.4 ± 170.1	1613.4 ± 122.6	1919.2 ± 194.0	1137.2 ± 48.1	2328.8 ± 160.1
Kidney fat (%)*	0.64 ± 0.0589	0.89 ± 0.0446	1.10 ± 0.0863	0.78 ± 0.0368	1.12 ± 0.0839
Omental fat (g)	1520.4 ± 151.5	1868.5 ± 122.8	2299.1 ± 126.8	1569.9 ± 59.2	2478.0 ± 121.4
Omental fat (%)*	$0.71^c \pm 0.0570$	$1.03^b \pm 0.0494$	$1.37^a \pm 0.0482$	1.09 ± 0.0521	1.19 ± 0.0651
Back fat thickness (mm)	$1.06^a \pm 0.18$	$2.39^b \pm 0.39$	$4.19^a \pm 0.46$	$2.11^b \pm 0.25$	$3.99^a \pm 0.50$
Meat characteristics					
pH_{24}	5.62 ± 0.07	5.60 ± 0.03	5.50 ± 0.05	$5.48^b \pm 0.05$	$5.64^a \pm 0.02$
Drip loss (%)	1.46 ± 0.18	1.57 ± 0.09	1.55 ± 0.12	1.64 ± 0.09	1.44 ± 0.10
Cooking loss (%)	34.6 ± 0.48	33.3 ± 0.51	32.9 ± 0.56	34.2 ± 0.23	32.4 ± 0.60
Colour					
L*	34.84 ± 0.60	35.69 ± 0.50	35.21 ± 0.29	$36.59^a \pm 0.30$	$34.03^b \pm 0.25$
a*	13.04 ± 0.40	13.14 ± 1.48	13.97 ± 0.29	$12.63^b \pm 0.20$	$14.44^a \pm 0.24$
b*	9.33 ± 0.40	9.47 ± 0.26	9.89 ± 0.27	9.65 ± 0.20	9.66 ± 0.28

[a,b,c] Column means within breed and slaughter age with different superscripts differ (P < 0.05)
[#] SX = Simmentaler crosses; BX = Bonsmara crosses; NG = Nguni;
* % of carcass weight
L*; 0 = black, 100 = white; redness (a*; + = red, - = green) and yellowness (b*; + = yellow, - = blue)

The only significant breed difference (across age groups) detected for any sensory trait was for sustained juiciness between meat from BX (mean = 6.71) and SX steers (mean = 6.14). No differences were detected between any of the breed x slaughter age combinations for tenderness (Table 2). However, when the data were pooled for slaughter age, the panel rated meat from steers from the 30-month old group tougher (P < 0.05) than meat from the 18-month old group. Although no interaction (P > 0.05) occurred between breed and slaughter age regarding WBS-values (Table 2), SX steers presented a higher (P < 0.05) value (3.52 ± 0.16 kg/12.7 mm diameter) than either BX (2.63 ± 0.85 kg/12.7 mm diameter) or NG steers (2.87 ± 0.15 kg/12.7 mm diameter). Furthermore, WBS-values were higher (P < 0.05) at 30 months (3.16 ± 0.15 kg/12.7 mm diameter) than at 18 months of age (2.62 ± 0.13 kg/12.7 mm diameter).

Table 2 Rank means (mean) for the sensory quality characteristics and means (± s.e.) for shear force values of the *Longissimus* muscle as influenced by different beef breed and slaughter age (months) combinations

| Breed[#] | SX | BX | NG | SX | BX | NG |
Age	18	18	18	30	30	30
Aroma[a]	1.820 (5.960)	1.814 (5.857)	2.029 (6.057)	2.100 (6.133)	1.660 (5.920)	1.880 (6.160)
Initial juiciness[b]	2.120 (6.600)	1.829 (6.486)	1.800 (6.343)	2.000 (6.467)	1.920 (6.560)	1.680 (6.400)
Sustained juiciness[c]	1.880 (5.640)	1.971 (5.742)	1.829 (5.543)	2.033 (5.600)	2.060 (5.920)	1.520 (5.360)
Tenderness[d]	2.100 (6.400)	2.043 (6.629)	1.600 (6.114)	1.933 (5.200)	2.000 (5.720)	1.640 (5.480)
Residue[e]	2.120 (6.680)	2.000 (6.743)	1.629 (6.486)	1.833 (5.733)	2.060 (6.600)	1.640 (6.160)
Flavour[f]	2.020 (6.240)	1.757 (5.743)	1.943 (6.057)	1.900 (5.867)	1.980 (6.280)	1.680 (6.040)
Shear force[h]	3.27 ± 0.12	2.37 ± 0.20	2.66 ± 0.20	3.71 ± 0.23	2.98 ± 0.25	3.07 ± 0.23

[#] SX = Simmentaler crosses; BX = Bonsmara crosses; NG = Nguni
[a] 1=Extremely bland; 8=Extremely intense   [b] 1=Extremely dry; 8=Extremely juicy
[c] 1=Extremely dry; 8=Extremely juicy   [d] 1=Extremely tough; 8=Extremely tender
[e] 1=Abundant; 8=None   [f] 1=Extremely unflavoured; 8=Extremely flavoured
[g] 1=Abundant; 8=None   [h] kg/12.7 mm diameter

Discussion

Differences in LW and CCW among the breed types used in this study are in general agreement with results from previous studies that the larger frame-sized breed types attain heavier final weights and have heavier carcasses than the smaller frame-sized breed type. Heavier (P < 0.05) LW and carcass weights have been reported for large-framed steers than for small-framed steers at a constant age (Wheeler *et al.*, 1996; Camfield *et al.*, 1999; Short *et al.*, 1999) as well as at a constant carcass fat content (Tatum *et al.*, 1986b; Dolezal *et al.*, 1993; Wheeler *et al.*, 1996). Bidner *et al.* (1986) reported similar LW for pasture raised Angus x Hereford and Brahman cross steers at 31 months of age, as was observed for SX and BX steers in the present study. Schaake *et al.* (1993), however, reported appreciably higher warm carcass weights (281.9 kg and 291.4 kg) for steers slaughtered from pastures at approximately 18 months of age.

Higher DP have been reported for intensively fed cattle (Schroeder *et al.*, 1980; Bidner *et al.*, 1986; Swanepoel *et al.*, 1990; Bennett *et al.*, 1995; Keane & Allen, 1998; Strydom *et al.*, 2001) than for forage fed cattle. This was mainly ascribed to less body fill as well as a higher carcass fat content in intensively fed animals, and probably explains the low DP observed in this study. The DP obtained in the current study are in general agreement with the results of Bidner *et al.* (1986), but contrary to the findings of Prior *et al.* (1977), Dolezal *et al.* (1993) and Camfield *et al.* (1999) who reported higher (P < 0.05) DP for large-framed steers than for small-framed steers, and Swanepoel *et al.* (1990) who noted that NG bulls had higher DP than Afrikaner and Pedi bulls, all under intensive feeding conditions. Although increased DP with increased age was observed in previous studies (Short *et al.*, 1999), in the present study DP of steers slaughtered in the 18 month and 30 month old groups were similar.

In concurrence with the results from this study, Swanepoel *et al.* (1990) reported that carcass compactness increased with increasing animal age. These authors also reported higher carcass compactness for NG bulls than for Afrikaner and Pedi bulls, which is contrary to the observations made in the present study. Strydom *et al.* (2001) reported higher carcass compactness for Bonsmara (0.91 to 0.94) and Nguni (0.74) bulls than was observed for 30-month old steers in the present study. The observed differences in

carcass compactness between the respective breed types are in agreement with the results of Tatum *et al.* (1986b) who indicated that there is a strong correlation (r = 0.96) between hip height and frame size, but a low correlation (ranging from 0.09 to 0.48) between other body measurements (body length, width and girth) and frame size. They indicated that although all body measurements increased with an increase in frame size, body length, width and girth were not always proportional to corresponding differences in heights. Large-framed animals thus tend to be disproportionately tall with relative short and narrow bodies compared to small-framed cattle that were short, but relatively highly developed in length, width and girth.

In studies with intensive feeding regimens differences between breeds regarding the various fat parameters have been reported. Breed differences in BFT were reported by Koch *et al.* (1979), Loveday & Dikeman (1980), Tatum *et al.* (1990) and Wheeler *et al.* (1996) at constant weight as well as age end-points, while Camfield *et al.* (1999) observed higher (P < 0.05) BFT and KPH fat percentages for steers of smaller framed breed types compared to steers of larger framed breed types. Swanepoel *et al.* (1990) did not observe any significant breed differences in BFT between Afrikaner, NG and Pedi bulls, but the percentage kidney and channel fat was higher for Pedi bulls than for Afrikaner (P < 0.05) and NG bulls (P < 0.01). On the contrary, Tatum *et al.* (1990) did not observe breed differences in kidney, pelvic and heart (KPH) fat percentage between Piedmontese, Gelbvieh and Red Angus steers. Swanepoel *et al.* (1990) did not observe significant differences in OF percentage between the different breeds. At equal BFT, Simmentaler cattle had significantly (P < 0.05) more KPH fat than Angus cattle (Crouse *et al.*, 1985a). However, Block *et al.* (2001) found no significant differences in body cavity fat percentage at equal BFT between Angus, Charolais and Hereford steers.

On lower energy diets the differences between breeds become less pronounced or in most cases even trivial. Sprinkle *et al.* (1998) reported no significant differences in BFT, KPH fat and OF among British, Tuli, Boran and Brahman steers with limited access to a maize-based diet, but differences between breeds were significant (P < 0.05) when steers from these breeds had *ad libitum* access to the diet. Increased BFT as well as KF percentage with increasing grain feeding were also observed by Bowling *et al.* (1977), Young & Kauffman (1978), Danner *et al.* (1980) Schroeder *et al.* (1980), Newsome *et al.* (1985), May *et al.* (1992) and Schaake *et al.* (1993), while Prior *et al.* (1997) reported that BFT and KPH fat of small-framed breeds increased significantly (P < 0.05) with increasing energy level in the diet, but not that of large-framed breeds.

Although Bidner *et al.* (1986) observed higher BFT for pasture raised Hereford-Angus cross steers than was observed in the present study, the results observed for the respective fat parameters of the present study are in general agreement with previous studies. In concurrence with the conclusion of Short *et al.* (1999) the effect of the sire breed on fat parameters became more pronounced with increasing age.

Even though NG steers had a higher percentage internal fat than the SX and BX steers, their dressing percentage was similar to that of the SX and BX steers. The reason for this is possibly due to the relatively lighter hide (Swanepoel *et al.*, 1990) of NG as well as differences in fat partitioning. Swanepoel *et al.* (1990) reported that at a LW of 390 kg, hides from NG bulls weighed approximately 1.5 kg less than that of Afrikaner bulls. The NG steers also accumulated more carcass fat than the other breeds as the BFT for the 30-month old steers were double that of the 18-month old steers, while BFT of BX increased with 84% and that of SX steers with 16%.

Although breed did not have a major effect on the meat quality attributes (drip loss, cooking loss, colour, pH_{24}, panel tenderness and WBS-values), slaughter age did. The meat was more tender at 18 months of age than at 30 months of age (P < 0.05) while the pH_{24} was also lower at 18 months of age (P < 0.05). The pH_{24} was not high enough to result in dark cutting meat. It appears that meat quality was probably influenced by carcass fatness and consequently cooling rate rather than by *ante mortem* muscle glycogen concentration.

Although Keane & Allen (1998) observed no significant differences in drip loss due to feeding system, they noted differences (P < 0.05) among light and heavy slaughter groups. Crouse *et al.* (1984) reported cooking losses for grain as well as pasture raised steers that are similar to that observed in the present study. Camfield *et al.* (1997) reported that although cooking loss was similar for meat from steers fed for 0 and 90 days it was higher (P < 0.05) than for meat from steers fed for 30 and 60 days. Comparing Afrikaner, Nguni and Pedi bulls, Swanepoel *et al.* (1990) observed no breed differences in the cooking loss of the *longissimus* muscle, but Whipple *et al.* (1990) observed that cooking loss increased as the percentage of *Bos indicus* increased.

Young & Kauffman (1978) and Newsome *et al.* (1985) reported very little dietary effects (forage *vs.* grain fed) on the subjectively evaluated lean colour of carcasses. However, Newsome *et al.* (1985) found that

at 3 days *post mortem* steaks from grain fed steers had a higher (P < 0.05) reflectance of light than steaks from forage fed steers. Similarly, Schroeder *et al.* (1980), Bidner *et al.* (1986), Schaake *et al.* (1993) and Bennett *et al.* (1995) reported that forage-fed steers had darker meat (subjectively measured) than grain-fed steers. Similar results were reported by Keane & Allen (1998) for objectively measured Hunter lab L* colour values among *longissimus* muscle steaks from intensively and extensively reared steers. Keane & Allen (1998) also reported higher a* (P < 0.05) and b* colour values (P < 0.001) for *longissimus* muscle steaks from intensively raised steers than for *longissimus* muscle steaks from extensively raised steers.

Devine *et al.* (1993) observed that muscle from young lambs (7 months of age) has lower (P < 0.05) ultimate pH values than that from older lambs (14 months of age), which is similar to what was observed in the present study. Young *et al.* (2004) concluded that the most desirable range for muscle pH that results in the best properties for table cuts is 5.4 to 5.6. Results of Devine *et al.* (1993) support this conclusion as they reported that WBS-values increased as the ultimate pH increased from 5.5 to 5.9 and also that WBS-values of meat from young and older animals with similar pH-values were similar. Devine *et al.* (1993) concluded that age-related tenderness effects were minor compared to pH effects. Rees *et al.* (2003) indicated that the rate of pH and temperature decline can influence tenderness due to two main factors; (1) Cold shortening occurs when the temperature falls below 10 ºC while muscle pH is still above 6.0 and (2) if the temperature declines slowly and pH rapidly, protein denaturation may occur. The latter event leads to a reduction of the proteolytic processes necessary for tenderization of meat. The fat thickness of the carcass is believed to be associated with a part of the difference in tenderness of beef due to its effect on temperature decline and thus also pH decline. Bowling *et al.* (1977) reported that sarcomere length and panel tenderness ratings increased while shear force values decreased when fat thickness increased from 1.27 mm to 8.9 mm, while May *et al.* (1992) found no improvement in tenderness after steers reached a BFT of 7.6 mm. Although the role of pH cannot be ignored completely, it is doubtful that pH had a major influence on the tenderness of the meat in the present study. Most probably the natural aging processes and their effect on the content and properties of collagen as explained by Hill (1966), Bailey (1985) and McCormick (1994) played a more prominent role. Although the pH_{24}-values of the steers slaughtered at 30 months fell marginally outside the range defined by Young *et al.* (2004), the WBS-values and sensory panel tenderness ratings were still within acceptable tenderness norms. Any WBS-values higher than 5.0 kg (Whipple *et al.*, 1990) were deemed unacceptable, while panel tenderness scores between 6.82 and 7.44 (scale of 1 to 9) were deemed moderately tender by Koch *et al.* (1979). Although a trained sensory panel identified differences in tenderness between steers slaughtered at 18 and 30 months of age, these differences were not large and were within a moderately tender class. It is thus unlikely that consumers will discriminate against beef from 30-month old steers compared to beef from 18-month old steers.

The present results are contrary to the results of Casey *et al.* (1990) who did not observe any breed differences in WBS-values or sensory panel tenderness of the *longissimus* muscle of Afrikaner, NG and Pedi bulls. Crouse *et al.* (1985a) did not find significant differences in WBS-values or sensory panel tenderness of *longissimus* and *semimembranosus* steaks from Angus and Simmentaler cattle. Although Strydom *et al.* (2001) did not find significant differences in WBS-values between different strains of Bonsmara or NG bulls, sensory panel tenderness differed (P < 0.05) among the different strains. In contrast, Strydom *et al.* (2000) reported in earlier research that although Santa Gertrudis bulls had higher (P < 0.05) WBS-values than Bonsmara, Pinzgauer, Brown Swiss, Afrikaner and NG bulls, sensory panel tenderness did not differ significantly between the various breeds. Similar results were reported by Koch *et al.* (1979), Knapp *et al.* (1989) and Wheeler *et al.* (1996). On the other hand, Whipple *et al.* (1990) reported that WBS-values for *longissimus* muscle steaks increased (P < 0.05) and that sensory panel tenderness decreased (P < 0.01) as the percentage *B. indicus* increased, but not in steaks from the *semimembranosus* muscle.

Mixed results were reported for dietary effects (especially the effect of energy or grain content) on WBS-values and sensory panel traits of beef. Prior *et al.* (1977) reported little influence of dietary energy and protein level on WBS-values and sensory traits of meat from small-framed Angus x Hereford and large-framed Charolais and Chianina steers and concluded that all carcasses of both types of cattle had acceptable palatability. Significantly higher WBS-values and lower tenderness ratings were observed for pasture-finished than for grain-finished steers (Bowling *et al.*, 1977; Schroeder *et al.*, 1980). Schaake *et al.* (1993) as well as Bennett *et al.* (1995) reported lower WBS-values for *longissimus* muscle steaks of feedlot steers than for steaks of pasture raised steers, but steaks of pasture fed steers were rated more tender than steaks of feedlot fed steers by a trained sensory panel. Short *et al.* (1999) observed that WBS-values decreased

(became tender) and that sensory panel tenderness increased (P < 0.01) with increasing time on a feedlot diet. Although the results of Camfield *et al.* (1997) and Keane & Allen (1998) also indicate a tendency for WBS-values to decrease and sensory panel tenderness ratings to increase with increasing time in a feedlot, it was not significant. Crouse *et al.* (1984) and Bidner *et al.* (1986) reported no effect of diet on WBS-values or sensory panel tenderness of the *longissimus* muscle. Although Crouse *et al.* (1985b) also observed no significant influence of diet on the WBS-values of meat, the sensory panel rated meat produced on a low energy diet to be more tender (P < 0.01) than meat produced on a high energy diet.

Koch *et al.* (1979), Knapp *et al.* (1989), Whipple *et al.* (1990), Wheeler *et al.* (1996) and Strydom *et al.* (2000) reported similar results for juiciness and flavour. Breed differences (P < 0.05) for connective tissue amount and flavour intensity scores, but not for juiciness scores were observed by Tatum *et al.* (1990). Whipple *et al.* (1990) observed that the connective tissue amount score (similar to residue in Table 2) decreased (became more) with increasing *B. indicus*, but similar to the results of the present study, Knapp *et al.* (1989) and Strydom *et al.* (2000) found no significant difference among breeds in the score for connective tissue amount with increasing *B. indicus*. Casey *et al.* (1990) found no significant differences between breeds for juiciness, flavour and residue, but residue score increased with increasing slaughter weight. Keane & Allen (1998) observed higher juiciness scores at higher slaughter weights. Juiciness scores also increased with increasing levels of marbling, but flavour intensity was not affected significantly (Wheeler *et al.*, 1996).

Crouse *et al.* (1985a) observed no breed effects for juiciness, flavour and connective tissue amount, but the meat from the low energy diet had a lower connective tissue content (P < 0.01) and flavour intensity score (P < 0.05) than beef from the high energy diet. Similar results were reported by Bowling *et al.* (1977), Schroeder *et al.* (1980), Bidner *et al.* (1986) and Bennet *et al.* (1995). Camfield *et al.* (1997) and Short *et al.* (1999) reported that connective tissue content and flavour intensity scores increased with increased time on feed, but juiciness was not affected by time in a feedlot. Similarly, May *et al.* (1992) observed that connective tissue content scores increased with increasing time in a feedlot, but juiciness and flavour intensity were not affected. In contrast, no significant differences in sensory panel scores were observed for beef from grain and pasture fed heifers (Crouse *et al.*, 1984) and varying levels of energy in the diet (Prior *et al.*, 1977). Inconsistent results for juiciness and connective tissue content for beef produced from pastures and various times in a feedlot were also reported by Schaake *et al.* (1993), while Young and Kauffman (1978) observed lower (P < 0.05) juiciness and higher (P < 0.05) flavour intensity scores for forage fed compared to grain fed steers.

It seems from the results of the present as well as previous studies that breed as well as diet only has minor effects on the sensory traits of beef. It also seems that animal age at slaughter has a more distinct effect on the sensory traits.

Conclusions

While breed and slaughter age influenced LW and carcass traits significantly, age at slaughter, which is the product of age as well as the environment, had a much more pronounced influence on meat quality traits than breed, possibly the result of the combined effects of fatness, pH and collagen characteristics. Steers from small-framed breed types (born from October to December) grazing natural sweet veld pastures will to some extent be finished off sufficiently for slaughtering at the end of the wet summer season at an age of 18 months and will be finished off to a greater extent at 30 months of age. On the other hand, steers from medium-framed breed types will only be successfully finished off for slaughtering at 30 months of age. Carcasses of steers from small-framed breed types may, however, be too small (mean = 134 kg) at 18 months of age to be readily accepted by the market. It may thus be beneficial to supplement or even feedlot steers to be slaughtered before the age of 30 months of age. This aspect, however, requires further research to determine the nutritional and cost implications that may result from this practice. As WBS-values and sensory panel tenderness scores were within moderately tender norms, it is doubtful that consumers will discriminate against beef from pasture-raised steers slaughtered at 30 months of age. Rigid slaughtering ages at the end of the wet season were used in this study. Undoubtedly the quality of the grazing was already in a decreasing phase. Thus, it is possible that steers may have been in a better condition prior to 18 and 30 months of age. Visual appraisal from 15 and 26 months of age onwards may identify animals suitable for slaughtering at a slightly younger age.

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