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Evaluation of growth, carcass and meat quality characteristics of grain-fed Charolais and Charolais x Nguni bulls

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Abstract

The study investigated the effect of crossbreeding Charolais bulls with Nguni cows on carcass and lean yield and meat quality characteristics. The intact Charolais bulls (n=10) served as control group against the Charolais x Nguni (n=10). The Nguni dam proved a good option for a dam line because of the hardiness of the breed, its mothering ability, ease of calving, and low maintenance cost. In contrast, the Charolais had excellent growth and carcass characteristics. It was a late maturing breed with better growth performance and higher yields than Charolais x Nguni, which could be classified as a medium maturing beef breed. Over the same duration and conditions of feeding the Charolais calves had better feed conversion and growth rates and produced larger carcasses than Charolais x Nguni calves. Owing to the large difference in carcass size, the Charolais had better meat to bone ratio than the Charolais x Nguni (P <0.001). Both breeds produced meat with a desirable appearance and good eating quality and no differences were recorded in the related traits. It could be concluded that Charolais and Charolais x Nguni weaned calves were well suited to the grain-fed market and would produce meat of acceptable quality.

Keywords: calpains, cross-breeding, meat colour, meat tenderness
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Introduction

Efficiency of meat production is continuously under pressure for economic and environmental reasons. On the one hand, estimated exponential human population growth to 8.9 billion in 2050 – coupled with increased per capita consumption of meat by the growing middle class in developing countries – would lead to an increase in demand of 32% for meat in developing countries and 14% in developed countries by 2030 (Alexandratos *et al.*, 2006). On the other hand, agriculture and meat production contribute to a large proportion of anthropogenic greenhouse gasses and to the carbon footprint (Steinfeld *et al.*, 2006). Advancements in genetics, nutrition, animal health management and reproductive performance could reduce greenhouse gasses (Capper, 2011; Place *et al.,* 2011; Mokolobate et al., 2019). Opinions are divided about optimal animal size in relation to sustainable production and production efficiency. It seems that this controversy revolves around production systems. For rangeland production, Scasta *et al.* (2016) reported that smaller cow size allowed for larger herds, leading to higher beef yields and a higher efficiency ratio. In contrast, under intensive production systems, animals with higher slaughter weights were sought after (Capper, 2011; Place *et al.,* 2011).

Africa has a large number of indigenous breeds that have adapted to climatic conditions (Scholtz, 1988; Scholtz & Lombard, 1992; Mirkena *et al.*, 2010; Scholtz *et al.*, 2010; Marufu *et al.,* 2011; Mokolobate *et al., 2*014). Since most beef animals produced in South Africa are grain fed, the low mature size of the Nguni negates its favourable characteristics. Scholtz & Theunissen (2010), supported by Calegare *et al.* (2007), therefore proposed that the Nguni cow should be used in terminal crossbreeding programmes using larger beef breeds as sire lines. Offspring should then be finished in grain-fed systems. Dystocia has long been a concern with the use of terminal sire breeds (Sagebiel *et al*., 1969). Scholtz & Theunissen (2010) recorded no calving difficulties when Chianina, Charolais, Simmental and Hereford were used as sire lines on Nguni cows and concluded that the Nguni dam could suppress birth weight without material consequence for

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subsequent growth. The ratio of weaning weight of the calf to the dam weight, the estimate of cow herd productivity, was 57.2 for the Charolais-Nguni cross compared versus 49.3 for the pure Nguni and 43.8 for the national average of all breeds in South Africa. In efficiency parameters (Scholtz & Theunissen, 2010), the Charolais was superior when utilized as terminal sire in cross-breeding, which agreed with Olentine *et al.* (1976), Southgate *et al.* (1982), Baker *et al.* (1987), and Casas & Cundiff (2003). Charolais-Brahman crossed steers grown on pasture and in feedlots also showed superior carcass characteristics to Brahman crosses with Santa Gertrudis, Hereford, Angus and Shorthorn, and were matched only by Limousin crosses (Schutt *et al.,* 2009a).

Compared to other breeds tested under the National Beef Cattle Performance Testing Scheme (Anonymous 2010), Charolais ha higher growth potential. However, because of the climate, the pure bred Charolais is not suitable for large parts of southern Africa.

Although carcass yield and efficiency will be of paramount importance in meeting increased demand for meat over the next decades, consumers have the final say in appearance and palatability of the product (Acebrón & Dopico, 2000; Grunert *et al.,* 2004). MacNeil & Matjuda (2007) emphasised traits such as calf survival and weaning weight when using the Charolais as sire breed on the Nguni dam in a multi-trait selection programme. In this study the authors attempted to demonstrate the suitability of the Nguni dam and Charolais sire, by characterizing the carcass and meat yield and meat quality of Nguni-Charolais crossbred animals compared with purebred Charolais under grain-fed conditions.

Materials and Methods

The procedures for sourcing, transporting, feeding and slaughtering the animals were approved by the Animal Ethics Committee of the Agricultural Research Council (ARC), Animal Production Campus (APIEC 01/2003). Treatment groups consisted of 10 intact male animals of pure Charolais origin and 10 intact male Charolais-Nguni crosses. Charolais weaned calves, 8–9 months old and unrelated to each other, were selected and supplied by the Charolais Cattle Breeders' Society of South Africa as a representative group of Charolais animals. Charolais-Nguni crosses were selected from the crossbreeding scheme of the ARC at Loskop Experimental Farm (25.1674° S, 29.3987° E), Groblersdal, Mpumalanga, South Africa. The Nguni cows that produced these calves had been inseminated by selected Charolais bulls provided by the Charolais Cattle Breeders' Society of South Africa.

All the animals were weighed twice on consecutive days, tagged and processed upon arrival at ARC-Animal Production Research Institute, Irene, Gauteng, South Africa, where they were grain fed and slaughtered. All yield and meat quality evaluations were performed at the same institute. Anabolic implants were not applied. Because of poor rainfall and thus early weaning, Charolais-Nguni animals (average weight 171 kg) were adapted to concentrate for 21 days to a starting weight of 190 kg. Charolais animals were adapted for 14 days. The animals of each group were kept in two feeding pens (10 m x 20 m). Feed intake was monitored on a group basis. After initial processing, live weights were recorded weekly to determine average daily gain (ADG). A balanced dry feedlot ration, providing 11 MJ ME energy/kg, 135 g crude protein/kg, 4 g phosphorus/kg , 8 g calcium/kg and 80 g crude fibre/kg on a dry matter basis (DM), was used throughout the trial (after adaptation). The diet consisted (DM base per/kg) of 62 g hominy chop, 15 g wheat bran, 10 g molasses meal, 5 g cotton oil cake meal, 4.5 g grass hay, 1.6 g feed lime, 1.3 g urea, salt and a vitamin/mineral premix.

Because of the relatively low starting weight, to reach a marketable carcass weight of at least 220 kg and fat code 2 (Anonymous, 1999), the Charolais-Nguni were grain fed for 140 days, whereas the Charolais calves were fed for 120 days. Carcasses were stimulated electrically (500 V, 2A output and 15 oscillations per second) after exsanguination. Warm carcass weights were recorded to calculate total yield and dressing percentage. Carcasses were chilled directly after dressing until a deep buttock muscle temperature of 10 °C was reached. Cold carcass weights were recorded before processing. One side of each carcass was processed into 15 retail cuts (Figure 1). Each cut was separated into meat (muscle and intermuscular fat), subcutaneous fat and bone. Carcass composition was calculated per cut and on an individual tissue basis (fat, bone and lean).

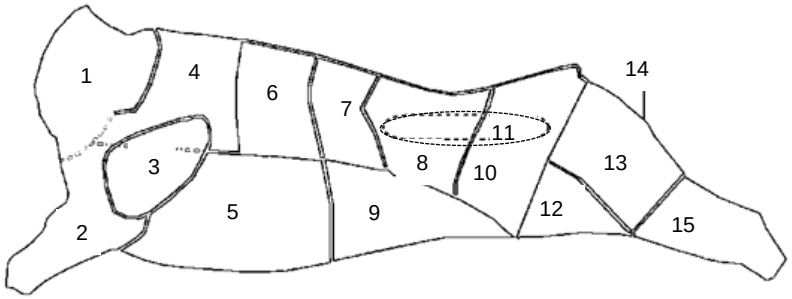

Figure 1 Diagram of carcass cuts according to the London and Home Counties cutting techniques (Gerrard & Mallion, 1977)

1: Neck, 2: Fore shin, 3: Shoulder, 4: Chuck, 5: Brisket, 6: Prime rib, 7: Wing rib, 8: Loin, 9: Thin flank, 10: Rump. 11: Fillet, 12: Thick flank, 13: Silverside, 14: Topside, 15: Hind shin; Forequarter cuts: 1, 3, 4, High-priced cuts: 6, 7, 8, 10, 11, 12, 13, 14; Ventral cuts: 5, 9; Shin cuts: 2, 15

All samples were collected from the *Musculus longissimus thoracis et lumborum* (LT, LL) from the eighth rib in the direction of the rump after rigor mortis. These tests were conducted: i) meat tenderness measured by Warner-Bratzler shear force (WBSF), and myofibril fragment length (MFL) on LL at three days and 14 days post mortem at 2 ± 1 °C; ii) sarcomere length measured at 24 hours post mortem; iii) proteinase enzyme measured as µ and m-calpain and calpastatin activity at 24 hours post mortem; iv) collagen properties; v) Instrumental colour on fresh samples 24 hours post mortem; and vi) proximate analyses of muscle fat (intramuscular fat).

Aged LL samples for WBSF were frozen at -20 °C and processed into 30 mm steaks with a band saw. The frozen steaks were thawed at 2 ± 1 °C for 24 hours and cooked with an oven-broiling (Mielé, model H217, Mielé & Cie, Gütersloh, Germany) method with direct radiant heat (American Meat Science Association (AMSA), 1995). The steaks were broiled at 260 °C (pre-set) to 70 °C internal temperature. Internal temperature was monitored individually with a 30-gauge thermocouple placed in the geometric centre of the steak and attached to a digital monitor (Comark C9003, Comark Ltd, Hertfordshire, UK). The steaks were turned when the internal temperature reached 35 °C to attain a final temperature of 70 °C before being removed from the oven and cooled to 18 °C. Six round cores (12.7 mm diameter) were removed from the steaks parallel to the muscle fibres (AMSA, 1995). Each core was sheared once through the centre, perpendicular to the fibre, with a Warner-Bratzler shear device mounted on Universal Instron apparatus (Model 4301, Instron Ltd, Buckinghamshire, England) (crosshead speed 20 mm/min). The means of six recordings were used as a shear value measured in Newtons.

Samples for sarcomere lengths of a fresh LT muscle (24 hours post mortem), were prepared (Hegarty & Naudé, 1970) with distilled water instead of Ringer Locke solution (Dreyer *et al.,* 1979). Fifty sarcomeres per sample were measured with video image analysis (VIA) with an Olympus B x 40 system microscope at 1000 x magnification equipped with CC12 video camera (Olympus, Tokyo, Japan). AnalySIS Life Science software package (Soft Imaging Systems Gmbh, Münster, Germany) was used to process and quantify measurements. Myofibril fragment lengths of LL aged for three days and 14 days post mortem were measured with VIA. Myofibrils were extracted according to Culler *et al.* (1978) as modified by Heinze & Bruggemann (1994). One hundred myofibril fragments per sample were examined and measured with an Olympus B x 40 system microscope at 400 x magnification. Samples collected for enzyme studies (24 hours post mortem) were snap-frozen in liquid nitrogen and preserved at -70 ºC. Calpastatin, µ-calpain and m-calpain were extracted from 5 g of the LL frozen samples (Dransfield,1996) and separated with the two-step gradient ion-exchange chromatography-method (Geesink & Koohmaraie, 1999). Calpain assays were determined with azo-casein as substrate (Dransfield, 1996). The use of azo-casein eliminates background absorbance of non-specific proteins in the extracts. One unit of calpain activity was defined as an increase in absorbance at 366 nm of 1.0 per hour, at 25 °C. One unit of calpastatin activity was defined as the amount that inhibited 1 unit of m-calpain activity. Results were expressed as units per gram of muscle. Frozen samples of the LL were analysed for collagen content and solubility (Bergman & Loxley, 1963; Hill, 1966; Weber, 1973) and for chemical composition of protein, fat, moisture and ash (AOAC, 2019).

Meat colour was measured with a Minolta meter (Model CR200, Osaka, Japan) on fresh samples (24 hours post mortem). Two freshly cut steaks of 15 mm thickness each of the LL were allowed to bloom for 60 minutes at chiller temperatures (4 ºC ± 2 ºC) before recording. Three recordings were performed on each steak. The data were obtained as L* (dark to light); a* (green to red) and b* (blue to yellow) values from

which colour intensity, chroma (S) saturation index = $((a^2 + b^2)^{1/2})$, and hue angle, or the movement away from the fundamental red colour, were calculated (MacDougal, 1977).

Data of WBSF, MFL and enzyme activities were subject to analysis of variance for a split-plot design using the GenStat® software (VSN International Ltd., Hemel Hempstead, UK). There were two breed groups (Charolais and Charolais-Nguni) as whole plots and two ageing periods (3 and 14 days, and 1 and 24 hours post mortem) as sub-plots. The rest of the data were subject to normal analysis of variance with breed as main effect. Statistical analyses were not performed on growth performance data because each breed type was fed in a single group and only raw mean values were tabled. The data were normally distributed with homogeneous treatment variances. No significant interactions were detected between breed and post mortem ageing. Means were separated with Fisher's protected t-test least significant difference at the 5% level of significance (Snedecor & Cochran, 1980).

Results and Discussion

Means for growth performance and carcass measurements are presented in Table 1. The Charolais and Charolais-Nguni started the trial at average live weights of 236 and 171 kg, respectively. The weight of the Charolais calves coincided with the national average weaning. However, the Charolais-Nguni calves were almost 20 kg heavier than the average Nguni weaning weight according to NBCIS (Anonymous 2010). The Charolais gained 800 g/day more weight than the Charolais-Nguni, and needed 0.5 kg less feed per kg weight gain. The Charolais gained 281 kg and the Charolais-Nguni 208 kg over 122 and 140 days. Charolais produced a carcass of 311 kg, 87 kg heavier than the Charolais-Nguni on average, and dressed out 1.5% points higher than the Charolais-Nguni because of higher slaughter weight. Larger animals at the same carcass fat level would dress out higher than smaller animals (Berg & Butterfield, 1978). Jones *et al.* (1984) and Strydom *et al.* (2008) confirmed this maturity type effect, accounting for the differences in dressing percentage to lower proportional yields of the fifth quarter parts for the larger animals.

Table 1 Means for growth performance and carcass characteristics of Charolais and Charolais x Nguni

Trait	Charolais	Charolais x Nguni
Starting weight, kg	234	191
Final weight, kg	515	379
Average daily gain, kg/day	2.3	1.5
Feed conversion ratio, kg feed/kg gain on dry matter basis	4.7	5.2
Daily feed intake, kg	11.1	8.3
Carcass weight, kg	312	224
Dressing %	60.5	59.0
Rib fat thickness, mm	2.6	2.9

The rib fat measurements of both breeds indicated very lean carcasses in the fat code 1 category (1.0 to 3.6 mm rib fat thickness; fat class range 0 to 6) (Government Notice R.342 of 19 March 1999). Average daily gain of the Charolais-Nguni was lower (200 g/day) but the feed conversion ratio (FCR) was better (1.1 kg feed per kg gain) than data recorded by Scholtz & Theunissen (2010). Whereas this study showed a better performance for Charolais-Nguni, the current study recorded much better performances for Charolais. The diet composition was not published, but animals were tested in the phase C performance testing programme, consisting of a 35-day adaptation period followed by a 140-day test. Diet composition might have contributed to the differences between the studies. Strydom *et al.* (2008) reported on feedlot performances of pure Nguni steers implanted twice with anabolic growth promoters and raised on the same diet as the present trial. In two trials Nguni gained 1.3 and 1.5 kg per day on average with FCRs of 5.2 to 5.9 kg feed/kg gain over 97 days and 132, respectively. The animals started the trial at 151 kg and 169 kg, which was higher in the second trial than the breed standard weaning weight of 151 kg (Anonymous 2010). In the light of this evidence, the growth potential of the Charolais-Nguni group was expected to be better, but could be ascribed to a low weaning weight, consequent slow adaptation to feedlot conditions, and double anabolic implants in the steer trial. Carcass weights of Charolais-Nguni bulls were higher than the first group of Nguni steers (188 kg) but the same as the second group, whereas Charolais-Nguni dressed out higher than both

groups (55% and 58% vs. 59%). Both Nguni groups were fatter than the animals in the present trial at slaughter (7 mm vs. 2.9 mm rib fat).

The carcass of the Charolais had slightly less subcutaneous fat (SCF) (P =0.08), significantly less bone (1.5% units) and more meat (meat = muscle + intramuscular fat) (2.3 % units) (P <0.001) than the Charolais-Nguni carcass (Table 2). Because the percentage of SCF (visible fat on the dressed carcass) was almost the same, it meant that for every kg bone the Charolais and Charolais-Nguni had 5.3 and 4.7 kg meat, a difference of 0.6 kg. Berg & Butterfield (1978), Kempster (1978), De Bruyn (1991) and Casas & Cundiff (2003) reported that carcasses of larger later maturing breeds had a greater meat to bone ratio at the same fatness, although there were exceptions. Kempster (1978) found that early maturing Angus showed a higher meat to bone ratio than the larger Simmentaler at a similar conformation score and SCF level.

Table 2 Carcass characteristics of Charolais and Charolais x Nguni bulls

Traits	Charolais	Charolais x Nguni	*P*-value	SE
Carcass tissue, g/kg carcass				
Subcutaneous fat	41	49	0.080	0.296
Meat	806	783	0.001	0.333
Bone	153	168	0.001	0.275
Kidney and channel fat, g/kg carcass	24	33	0.001	0.145
Meat to bone ratio	5.3	4.7	0.001	0.099
Total subcutaneous fat. Kg	6.1	5.2	0.137	0.411
Total meat, kg	118.0	81.5	0.001	1.430
Total bone, kg	22.4	17.4	0.001	0.410
Yields of different cuts, g/kg carcass				
Neck	92	89	0.295	0.2330
Chuck	81	93	0.001	0.1500
Shoulder	103	101	0.108	0.1066
Fore shin	54	53	0.333	0.0994
Prime rib	34	35	0.465	0.0513
Brisket	125	131	0.015	0.1680
Wing rib	29	29	0.585	0.0538
Hind shin	64	62	0.150	0.1014
Topside	80	82	0.049	0.0684
Silverside	83	79	0.065	0.1168
Thick flank	47	40	0.001	0.0864
Thin flank	77	70	0.013	0.1800
Rump	70	73	0.138	0.1470
Loin	42	46	0.025	0.1030
Fillet	18	18	0.975	0.0356
Composition of high priced cuts[1], g/kg carcass				
Subcutaneous fat	486	462	0.331	1.6700
Meat	429	435	0.182	0.2960
Bone	241	237	0.347	0.3080

[1]High priced cuts: prime rib, wing rib, loin, rump, silverside, topside, thick flank

The yields of 15 wholesale cuts were expressed relative to carcass weight. Significant differences were recorded between the breeds for the yields of the chuck, brisket, topside, thick flank, thin flank and loin cuts. However, these differences was relatively small and probably of little commercial significance. The differences were ≤0.4% for the neck, shin, shoulder, prime rib, wing rib, topside, silverside, loin, fillet and

rump; and between 0.5% and 0.9% for the thick flank, and thin flank, with only the chuck differing by 1%. Strydom *et al.* (2008) recorded yield from steers for the buttock that was trimmed only of excess SCF and intermuscular fat. Although carcass weight of the second Nguni group in that study was comparable with those evaluated in this study, trimmed fat was more than 12%, whereas trimming in the present trial would have been minimal. Therefore the Charolais-Nguni cross should yield more meat at comparable carcass fatness than pure Nguni. For similar reasons, the Charolais in this study yielded more meat (36 kg) than the Charolais-Nguni. When the proportional yields of the prime rib, wing rib, topside, silver side, loin, thick flank, fillet and rump were added together, there was no significant difference in the total high-priced cuts between the two breeds. These cuts made up 40% of the carcass weight. In addition, the distributions of SCF, meat and bone in the high-priced cuts were similar, so proportionally the two groups had the same distribution of tissue in the more expensive hindquarter cuts. On average, 24%, 43% and 47% of the total carcass bone, meat and SCF, respectively, were present in the high-priced cuts that are normally sold as deboned trimmed cuts. Strydom *et al.* (2000a) showed that there was little variation in distribution of meat, fat and bone among breeds, including the Nguni, when they were compared at a constant SCF level that was similar to that of the present trial. Schutt *et al.*(2009a) found that only Brahman-Limousin crossbreds had a higher retail beef yield adjusted to common carcass weights in a crossbreeding study that included Charolais, Belmont Red, Santa Gertrudis, Hereford, Angus, Shorthorn as sire breeds and pure Brahman. The Limousin and Charolais carcasses were leanest at a common carcass weight. This would have been the case in the present trial. The Charolais-Nguni recorded a higher proportion of kidney and channel fat than the Charolais (P <0.001) (Table 2). On average at carcass weights of 224 kg and 312 kg, the amount of kidney fat was 7.4 kg for Charolais-Nguni and 7.9 kg for Charolais.

Meat quality related data are presented in Table 3. Marbling, measured as intramuscular fat (IMF), did not differ between the two groups. Marbling level was very low ranging between 16.5 g/kg and 17.5 g/kg loin muscle, which could be attributed to the general young age and lean condition of both groups at slaughter. Schutt *et al.* (2009b) recorded an IMF fat level of 2.72% (27.2 g/kg) for Charolais x Brahman cross animals finished on pasture at two years old, whereas the P8 fat measurement was 9.1 mm. This IMF value was lower only than Shorthorn and Angus crosses, which also recorded higher P8 fat values.Shear force values for Charolais and Charolais-Nguni were similar at three and 14 days post mortem. In terms of threshold values for consumer acceptability (Shackelford et al., 1991) — namely 45 N and 38 N for 'retail' and 'food service' beef — two days ageing was not sufficient to ensure consumer satisfaction, irrespective of breed. Prolonged ageing would satisfy the consumer. According to Boleman et al. (1997), 95% of consumers would have paid a premium for the steaks that were aged for 14 days. Meat varies in tenderness at slaughter because of ante-mortem factors (breed, nutrition, age) and conditions during slaughter and then improves during post-mortem ageing (Koohmaraie et al., 2003). Electrical stimulation counteracts excessive rigor shortening in extreme chilling conditions, but could facilitate further improvement in tenderness via enhancing or accelerating proteolysis (Ferguson et al., 2000, Devine et al., 2001). Therefore, electrical stimulation contributed to the low final WBS values recorded for both breeds. With regard to rigor shortening, Marsh & Leet (1966) stated that post-mortem sarcomere length changes of less than 20% produced almost negligible effects on beef tenderness. If resting sarcomere length of bovine muscle were taken as 2.1 □m (Marsh & Carse, 1974), then mean percentage shortening for the Charolais and Charolais-Nguni would have been 9% and 18%, respectively. Therefore, shortening differences between the two groups in this low range (<20%) would be expected to exert little effect, although the slightly higher WBS value of the Charolais-Nguni at two days may have caused by mild shortening (toughening), despite electrical stimulation. Post-mortem tenderisation was characterized by measuring the amounts of active calcium dependent protease at 24 hours post mortem and of structural breakdown by measuring the myofibrillar lengths at two and 14 days post mortem. The calcium dependent protease system (CDP), consisting of two proteolytic enzymes, m- and mu-calpain and calpastatin, an inhibitor, is a significant role player in meat tenderization (Koohmaraie & Geesink, 2006) . Although m (P =0.079) and mu calpain (P = 0.055) activities tended to be higher in Charolais samples (P<0.10), this did not reflect in a higher level of tenderization in Charolais LL. In addition, the degree of myofibrillar breakdown (shorter MFLs) was the same for the two groups at three and 14 days, which supported the low and similar WBSF values at 14 days for both groups.

Table 3 Meat quality characteristic of the loin muscle of Charolais and Charolais x Nguni bulls

Traits	Charolais	Charolais x Nguni	*P*-value	SE
Intramuscular fat, g/kg	16.5	17.5	0.494	0.145
Warner-Bratzler shear force, N[1]				
2 days post mortem	51.4	53.0	0.723	0.321
14 days post mortem	30.0	29.2	0.763	0.192
Amount of ageing	21.4	23.8		
Histology				
Sarcomere length, µm	1.9	1.7	<0.001	0.028
Myofibrillar fragment length: 1 day post mortem, µm	34.6	32.2	0.206	1.277
Myofibrillar fragment length: 14 days post mortem, µm	25.8	24.0	0.416	1.500
Collagen characteristics, mg/g muscle				
Soluble collagen	1.55	0.82	<0.001	0.081
Insoluble or heat stable collagen	2.64	3.30	0.003	0.132
Proteolytic enzyme units/g sample[2]				
Calpastatin	1.93	2.01	0.641	0.117
m-calpain	0.95	0.86	0.079	0.035
µ-calpain	0.96	0.62	0.055	0.114
Moisture characteristics				
Drip loss, g/kg	26.4	28.8	0.413	0.202
Water binding capacity, ratio	0.37	0.38	0.358	0.009
Meat colour				
Reflectance, 0 to 100)	41.2	39.9	0.118	0.546
Chroma, vividness	17.1	17.2	0.868	0.635
Hue angle	27.3	25.0	0.070	1.193

[1]Shear force resistance: mechanical measurement of tenderness where higher values indicate tougher meat
[2]One unit of calpastatin activity is defined as the amount that inhibited one unit of m-calpain activity. Calpastatin was extracted from fresh sample. One unit of calpain activity is defined as an increase in absorbance at 366 nm of 1.0 absorbance unit per g of muscle per hour, at 25 °C. Calpains were extracted from frozen sample (-72 °C)

As well as sarcomere shortening and the CDP system, connective tissue properties (stromal proteins) are the third factor involved in tenderness. Connective tissue forms the basic framework of muscle structure and consists mainly of collagen. Because proteolytic weakening of this structure post mortem is limited (Nishimura *et al.*, 1995), connective tissue is involved mostly in baseline tenderness (Valin, 1995). Although the total LD collagen content of the breed types was the same, Charolais samples had a higher soluble (P <0.001) and lower heat stable collagen proportion (P =0.003) compared with the Charolais-Nguni. Similar to the differences in the CDP, µ-calpain, differences in collagen properties did not reflect in WBSF values. The total collagen concentration and mature crosslinks of muscle have an additive (negative) effect on meat tenderness (McCormick, 1994). However, the loin muscle is a low connective tissue muscle (Rhee *et al.*, 2004) and differences in connective tissue properties between the breeds did not probably play a significant role in tenderness expression.

The initial tenderness of the two breeds compared favourably with breeds from the first trial of Strydom *et al.* (2008) (Bonsmara, Nguni, Drakensberger, Tuli; implanted steers) and was better than that of the Brahman. Tenderness after ageing was slightly better (±5 N) in the present trial and coincided with shorter MFLs after 14 days compared with Strydom *et al.* (2008) after 14 days. Under slaughter conditions like those used in the present trial, the sarcomere lengths of the breeds in Strydom *et al.* (2008) were similar to those of the Charolais-Nguni (1.7µm). The total collagen levels compared favourably with various South African breeds (Strydom *et al.,* 2000b) (Bonsmara, Brown Swiss, Afrikaner, Nguni), whereas the soluble collagen portion of Charolais was much higher than these breeds (37% vs 15% to 21%) probably suggesting a breed

phenomenon. The soluble fraction of the Charolais-Nguni (20%) coincided with that of the Nguni (21%) in Strydom *et al.,* 2000b.

The ratios for bound water (water-binding capacity) and drip loss were the same for the Charolais and Charolais-Nguni. Similar values for the two attributes were reported by Strydom *et al.* (2008), whereas there was little variation among breeds such as Nguni, Bonsmara, Brahman, Drakensberger and Tuli. Similarly, Schutt *et al.* (2009b) recorded very small differences in cooking loss among breed crosses (Brahman dam), including Charolais, Limousin Hereford, Belmont Red, Santa Gertrudis, Shorthorn and Angus. Only pure Brahman recorded higher cooking loss. When related only to moisture loss, cooking loss is an indication of water-holding capacity (Honikel, 1998).

Colour is an important quality characteristic of meat for the consumer at the point of purchase. Most consumers prefer and willing pay premiums for bright cherry red coloured beef (Troy & Kerry, 2010). Colour can be adversely affected by numerous factors (Kropf, 1993, Manchini & Hunt, 2005). In the present study muscle colour was determined only at a single point after blooming. Neither chroma nor reflectance differed between groups. The hue angle of Charolais tended to be higher than that of Charolais-Nguni (P <0.07), indicating a less redness and more metmyoglobin in the Charolais samples. Therefore under controlled production slaughter conditions, small or no differences in meat colour are expected between these groups. Although actual trial conditions may have an effect on colour display in meat, Strydom *et al.* (2008) showed slightly higher values for chroma for Nguni loins in one trial and similar values in a second trial. Differences in chroma in both phases of the project were small, and only Bonsmara steers recorded higher chroma in phase 1 compared with other breed groups. Thus large breed differences in colour are not expected when production and processing conditions are ideal. Reflectance or lightness in the current trial corresponded with values reported by Strydom *et al.* (2008) for Nguni and other breeds.

Conclusions

Crossbreeding with extreme maturity types such as Nguni and Charolais produced carcass weight that should be more acceptable than that of the smaller breed. However, the carcass of the crossbred animal would have a lower meat-to-bone ratio in general, and a similar ratio in higher priced cuts of the hindquarter and mid carcass. The authors recommend a crossbreeding programme that utilizes a large frame sire breed such as the Charolais and a smaller frame dam breed such as the Nguni to produce high-quality carcasses suitable for a market aimed medium-size carcasses, that is, 220–230 kg. Such a programme would take advantage of the lower maintenance costs, reproduction efficiency and hardiness of the Nguni and superior growth and carcass characteristics of the Charolais.

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Authors' contributions

PES developed the original hypotheses, designed the experiments, collaborated in interpreting the results, and finalized the manuscript. PES and MHJ collected the data for this study, conducted the statistical analyses in collaboration with Mrs M. Smith, and collaborated in interpretation of the results. PES wrote the initial draft of this manuscript, and both authors read and approved the final manuscript.

Conflict of interest declaration

The authors have no conflict of interest relative to the contents of this study.

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