Meat Science 80 (2008) 86–93

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Review

Do indigenous Southern African cattle breeds have the right genetics for commercial production of quality meat?

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ARTICLE INFO

Article history:
Received 5 March 2008
Received in revised form 14 April 2008
Accepted 21 April 2008

Keywords:
Indigenous beef breeds
Tenderness
Yield
Growth performance
Pasture
Feedlot

ABSTRACT

The establishment of cattle breeds which are now indigenous to Africa is believed by historians to be very closely associated with man, his development, migration and specific behaviour from 6000 years BC. Today these breeds compete with exotic breeds in a commercial system driven by global economical principles. Results from various trials are discussed to verify if these breeds can adhere to these principles and compete in the South African beef market to produce quality beef economically. Variation in frame size among indigenous breeds will determine their suitability as feedlot cattle depending on the price and feed margins driving profit in this industry sector. Meat quality analyses indicate small or no differences between indigenous and exotic European/British breeds but with potentially superior quality compared to *Bos indicus* breeds.

Contents

1. Basic principles for quality beef production

Major beef producing countries like the USA and Australia agree that objectives for producing beef for export and local consumption have changed over recent years and are based on two basic principles:

1.1 The consumer has to be satisfied while the industry stays competitive with regard to price and profitably in production (Morgan et al., 1991; McKenna et al., 2002; Gaden, 2007).
1.2 All sectors of the industry must play their part to adhere to the first principle.

Apart from meat safety factors, attributes such as colour, aroma/flavour, juiciness and tenderness are collectively regarded as quality factors involved in a satisfied eating experience. Of these, tenderness is certainly the most important for consumer satisfaction, as witnessed by quality surveys, but is also the most influenced by every link in the supply chain (Morgan et al., 1991; Brooks et al., 2000; Thompson, 2002). Also in South Africa, a recent

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doi:10.1016/j.meatsci.2008.04.017

survey by AC Nielson (Unpublished) raised the concern about the effectiveness of the present beef value chain when beef was ranked fourth after chicken, fish and mutton for perception of tenderness.

2. The South African beef industry

Under this section a brief description of how the beef industry operates in South Africa is given to clarify later discussion on beef quality issues. The drive for profit and hence the focus on factors involving profit is, despite the smaller scale in South Africa compared to other major beef producing countries, amplified by the fact that more than 75% (1.35 million carcasses) of beef is produced through feedlots (SAFA, 2008a). This is in comparison with 35% for Australia (Gaden & Bertam, 2007) and much less for countries like Argentina, Brazil and New Zealand that mainly produce beef from natural pasture. More so than in the past, the global feedlot industry is under increasing pressure, due to exceptionally high grain prices, to use cattle types that are heavier at the same or younger age than in the past. For example, the average carcass weight of cattle from South African feedlots increased by 10% (from 226 kg to 250 kg), while both the weaner and carcass prices doubled over the last seven years (SAFA, 2008b). Age at entry into feedlots varies between 7 and 9 months (weaners) or at the most 10–12 months (long weaners). Therefore, as in other feedlot operations, the demand for suitable breeds and maturity types will dictate breeding and production objectives of the weaner calf producers in order to overcome shrinking margins.

The 25% (some sources indicate up to 40%) cattle produced from pasture are slaughtered at 2–4 years (oxen) or as old cull animals. Although a large proportion of South African farming land is suitable for grazing (85%; Anonymous, 2006), factors like inconsistent rainfall, overgrazing and the variation of biomes (from desert to tropical) limit the carrying capacity and therefore also dictate the type of breed used in different regions.

While most of the formal statistics on cattle and meat production exists for the commercial farming sector, a second and third group of farmers are also distinguished, namely communal and emerging farmers. The latter are in the process of entering the larger commercial sector, while the communal farmers are generally regarded as subsistence farmers. According to Olivier (2004), both groups are counted under the 24,0000 small commercial farmers providing to local, regional or informal markets. It is reported that this sector own 40% of the cattle in South Africa (5.7 million head), yet has only 10% of the market access (Winter, 2007). While other farming groups are not excluded, communal farmers are often characterized as having lower skills for pasture management practices leading to overgrazing and low quality stock (Bester, Matjuda, Rust, & Fourie, 2001).

3. The origin of indigenous African cattle and their history and role in South Africa

The establishment of cattle breeds which are now indigenous to Africa is believed by historians to be very closely associated with man, his development, migration and specific behaviour from 6000 years BC (Bachmann, 1983). Africa's indigenous cattle are believed to be a variation of crosses between humpless Hamitic longhorn cattle (*Bos taurus*) from Arabia, Zebu cattle from Asia (*Bos indicus*) and possibly humpless shorthorn cattle from Spain. As the migration of man continued southwards, new breeds and types evolved with some predominantly Zebu, such as the Boran, Masai, Sokoto, and others such as the Sanga types (also known as *Bos taurus africanus;* Afrikaner, Nguni, Pedi, Mashona and Tuli) showing genetic markers unique to both *Bos taurus* and *Bos indicus* cattle types (Meyer, 1984). Through the migration of certain human tribes to southern Africa (San and Sudanic Bantu), Sanga cattle breeds were brought to this region and dominated the cattle population when Europeans arrived during the 15th century (Bachmann, 1983). Natural selection to overcome environmental challenges such as Tsetse fly and East coast fever resulted in an animal type which is anatomically and physiologically adapted to harsh extensive conditions.

At the time the Europeans came to the south point of Africa new agricultural practices were developed and veterinary services were established over the years, less adapted *Bos taurus* breeds were imported for their perceived higher income coupled with better carcass quality (yield, fat distribution). Since the 1970's, when commercial feedlots started in South Africa it became common practice to finish cattle for the market, rather than from grass feeding, later maturing *Bos taurus* breeds became even more popular, to the detriment of indigenous cattle (Bachmann, 1983), which were regarded as inferior and were decimated through government decree (Bester et al., 2001). Another import, the Brahman (*Bos indicus*), was now utilised as a dam or sire line to overcome climatic challenges the *Bos taurus* breeds could not adapt to, and for its vigorous heterosis with taurus breeds. Even in communal areas the mistaken perception of the local breeds' inferiority (especially the Nguni), led to the dilution of the genetic gene pool through replacement and cross breeding with exotic breeds. Fortunately, a number of events took place since the 1940's that arrested the degradation of the indigenous gene pool of the various cattle breeds. The Drakensberger Breed Society was formed in 1947 in South Africa and the Tuli Breed Society formed in 1961 in Zimbabwe. The Bonsmara, a composite indigenous breed originated in the 1940's from 5/8:3/8 combination of the Afrikaner (indigenous) and Shorthorn/Hereford (Bonsma, 1980, breed society established in 1964) to take advantage of the combination of the growth performance, carcass quality, fertility and milkability (mothering ability) of British breeds (which was lacking for the Afrikaner at that stage), and the hardiness of the Sanga. The erosion (through government decree) of other indigenous breeds, such as the Nguni, was turned around by the scientific motivations of Prof Bonsma (Bonsma et al., 1951) with the benefit of a committee appointed in 1985 to report on the desirability of a germ plasm bank for the hardiness of the various Sanga breeds (Hofmeyr, 1994). This gave a resurgence of the Nguni's popularity under commercial breeders that increased exponentially over the last decade. At present 23,298 female animals are registered under the National Beef Recording and Improvement Scheme, only second to the indigenous composite Bonsmara with 52,924 registered female animals (Bergh, Vermaak, Gerhard, & Havenga, 2007). For this reason, carcass and meat quality presented and discussed will mainly focus on the Bonsmara and Nguni. Initiatives such as the Kelogg-Nguni Cattle Project (Muchenje, Dzama, Chimonyo, Raats, & Strydom, 2008), the Beef Profit Partnership funded by Australian centre for international agricultural research (ACIAR) (Winter, 2007; Strydom, Frylinck, Van der Westhuizen, & Burrow, 2008) and Southern African Development Community/FAO/United Nations Development Program (Bester et al., 2001) are focused on the rescue and development of indigenous breeds in the region and the introduction of communal farmers into the mainstream commercial beef supply chain by utilizing indigenous genetics.

Delayed age at puberty (Plasse, Warnick, & Koger, 1968; Cartwright, 1980), lower vigor of newborn calves (Reynolds, DeRouen, Moin, & Koonce, 1980), less intramuscular fat (Huffman, Williams, Hargrove, Johnson, & Marshall, 1990; Whipple et al., 1990) and less tender meat (Crouse, Cundiff, Koch, Koohmaraie, & Seideman, 1989; Wheeler, Savell, Cross, Lunt, & Smith, 1990; Shackelford, Koohmaraie, Miller, Crouse, & Reagan, 1991a) resulting from high percentage Brahman seems to be main reasons for the loss of popularity of this breed in the USA and probably many other countries, like Australia. In contrast, the specific qualities of indigenous Sanga cattle breeds, specifically under harsh tropical conditions, are well documented. They are known for high fertility (Nguni breed: Maule, 1973), low inter calf periods (Nguni: Scholtz, 1988), ease of calving (Schoeman, 1989), cow efficiency (kg calf per kg cow) (Nguni: Schoeman, 1989), adapted to poor grazing conditions for example due to maintenance of high blood urea (Meissner & Roux, 1982; Osler, Meyer, Linington, & van der Merwe, 1993) and have a high tick resistance (Afrikaner: Bonsma, 1980; Nguni: Schoeman, 1989).

4. Comparisons between indigenous and exotic breeds in relation to market demand

4.1. Growth performance and yield

Although the growth performance and carcass yield of certain Sanga breeds under intensive feeding conditions appear to be less favourable, compared to exotic breeds (Anonymous, 2000; Herring, Sanders, Knutson, & Lunt, 1996 (Tuli); Phillips & Holloway, 1995 (Tuli); Meissner & Roux, 1982 (Afrikaner)), there is evidence of variation in maturity types among these breeds and that certain performance characteristics are independent of breed type under certain intensive feeding conditions. According to Strydom et al. (2008); the Drakensberger, Tuli and Bonsmara gained weight faster and produced larger carcasses than the Brahman (*Bos indicus*) and the Nguni. However, growth performance tests of the National Beef Cattle Performance Testing Scheme, showed that the feed conversion ratio of the Nguni compared favourably with that of a number of later maturing breeds measured over the same number of days (Anonymous, 2000), while the work of Strydom et al. (2008) found that Nguni, Tuli, Drakensberger and Bonsmara (all indigenous) had similar feed conversion ratios (FCR) even over extended feeding periods (132 days) (Table 1). In this trial, it was also shown that herd of origin, meaning commercial, communal or emerging farming, had little influence on growth performance (FCR).

Considering the increased focus on higher yielding carcasses (high carcass weights, low fat trim) by feedlots, the Nguni and Afrikaner fall short of these objectives with carcass weights below 200 kg and significantly ($P < 0.05$ at a common subcutaneous fat level of 4.7%) lower than Bonsmara carcasses that were closer to market demand (238 kg) (Strydom, Naudé, Scholtz, & Van Wyk, 2000a). Despite the higher carcass weights of Bonsmara, they were outperformed by Santa Gertrudis, Brown Swiss and Pinzgauer ($P < 0.05$; Bonsmara vs. others) (Table 2). Marais (2007) also reported higher carcass weights for commercial Brahman (282 kg) and Simmental crosses (275 kg) compared to Nguni crosses (207 kg; $P < 0.05$) with no significant differences in fat cover among the breeds. Strydom et al. (2008) showed that herd origin and live weight (carcass condition) at start of feeding could influence the final carcass weight produced. Nguni from communal and emerging farmers could not reach 200 kg after 130 days on feed, while the same accounted for Bonsmara when their starting weights were lower than 200 kg. However, both emerging Bonsmara (256 kg) and Nguni (227 kg) reached favourable carcass weights when their starting live weights were closer to 200 kg. Carcass weights from the commercial indigenous breeders such as the Drakensberger (265 kg) and Bonsmara (270 kg) were well into the favourable carcass weight range. Trimmed retail yield values showed that the heavier Nguni carcasses tended to show lower proportions of trimmed meat yields and slightly more fat than the lighter Nguni carcasses and the other larger indigenous breeds. On the other hand, when compared at similar fat cover, the Nguni and Afrikaner had significantly smaller rib eye areas ($P < 0.05$) compared to the Bonsmara, Pinzgauer, Santa Gertrudis and Brown Swiss, but their muscle to bone ratio compared favourably to those of the larger breeds (Strydom et al., 2000a). In both these trials, when based on absolute yield (kg), the Nguni carcasses would have produced significantly less trimmed meat than the larger indigenous breeds.

In a recent trial where extreme crossbreeding between Charolais bulls and Nguni cows were investigated, the crossbred calves gained weight at lower rates (2.3 kg/day vs. 1.49 kg/day) and less efficiently (4.7 kg/kg vs. 5.2 kg/kg) than pure Charolais and reached an average carcass weight of 224 kg against the 312 kg of the Charolais (Trial report to South African Charolais Cattle Breed Society, February 2008; data unpublished). The proportional meat yield of the cross was significantly less than the pure Charolais (78.3% vs. 80.6%; $P < 0.05$) while the subcutaneous fat % was the same. Since both the groups were lean at slaughter, it was concluded that the carcass weight of crosses could be increased by longer feeding without producing excess fat.

Du Plessis and Hoffman (2007) reported on pasture finished Nguni crossbreeds compared to Simmental and Brahman crossbreeds and showed similar differences in frame size/physiological type than those found for the feedlot trials. At 18–30 months of age, the Nguni crosses were significantly fatter (4.2 mm back fat) but in more ideal body condition for the market than the Brahman crosses (2.4 mm) and Simmental crosses (1.1 mm). However, their mean carcass weight (166 kg) was significantly less compared to Brahman crosses (182 kg) and Simmental crosses (217 kg). Muchenje et al. (2008) showed that Nguni gained proportionally more weight compared to the Bonsmara and Angus under harsh extensive conditions but produced extremely low carcass weights (107 kg). None of the three breeds had any significant carcass fat cover.

Table 1
Growth performance and carcass characteristics of various Southern African indigenous breeds and the Brahman (Strydom et al., 2008)

	Commercial Bonsmara	Emerging Bonsmara	Emerging Brahman	Commercial Drakens-berger	Emerging Nguni	Communal Nguni	Tuli	s.e.
Weaning weight norm (kg)[a]	213	213	210	199	151	151	185	
Starting weight (kg)	214^{cd}	214^{cd}	212^{cd}	226^{d}	194^{b}	149^{a}	195^{bc}	7.55
Average days on feed	132	132	132	132	132	132	132	
ADG (kg/day)	1.70^{c}	1.70^{c}	1.52^{b}	1.76^{c}	1.51^{b}	1.33^{a}	1.70^{c}	0.0475
FCR (kg/kg)	5.60	5.60	5.41	5.69	5.95	5.51	5.42	0.200
Final weight (kg)	434^{cd}	434^{cd}	413^{bc}	454^{de}	391^{b}	324^{a}	418^{c}	8.42
Cold carcass weight (kg)	256^{c}	256^{c}	235^{b}	265^{c}	227^{b}	181^{a}	241^{b}	5.29
Round meat yield (%)[f]	72.9^{ab}	72.9^{ab}	72.1^{ab}	72.5^{ab}	72.5^{ab}	71.8^{a}	73.0^{ab}	0.546
Trimmed fat (%)[f]	10.8^{ab}	10.7^{ab}	10.9^{ab}	11.3^{ab}	11.4^{ab}	12.0^{b}	10.5^{ab}	0.556
Bone yield (%)[f]	16.4^{a}	16.4^{a}	17.1^{b}	16.2^{a}	16.1^{a}	16.2^{a}	16.5^{ab}	0.254

[a] Official 205-day weight for each breed recorded by the National Beef Cattle Improvement Scheme (Anonymous, 2000).

[bcde] Means within each row followed by a different letter are significantly different at $P < 0.05$.

[f] Composition of retail trimmed round: meat, trimmed fat and bone as a% of round weight.

Table 2
Slaughter weight and selected carcass characteristics of various Southern African indigenous and exotic breeds adjusted to the overall mean subcutaneous fat proportion (47 g/kg) (Strydom et al., 2000a)

	Afrikaner	Nguni	Bonsmara	Santa Gertrudis	Pinzgauer	Brown Swiss
Slaughter weight (kg)	337 ± 2.3^{b}	298 ± 1.8^{a}	415 ± 1.1^{c}	443 ± 2.6^{d}	440 ± 3.5^{d}	462 ± 3.8^{e}
Carcass weight (kg)	182 ± 1.9^{b}	168 ± 1.5^{a}	239 ± 0.9^{c}	255 ± 2.1^{d}	253 ± 2.8^{d}	271 ± 3.1^{e}
Eye muscle area (cm^2)	69.0 ± 2.4^{a}	69.3 ± 2.4^{a}	79.5 ± 1.1^{bc}	73.3 ± 2.4^{ab}	83.4 ± 2.4^{bc}	86.2 ± 2.4^{c}
Muscle to bone ratio	4.4 ± 0.1^{ab}	4.2 ± 0.1^{a}	4.5 ± 0.1^{b}	4.0 ± 0.1^{a}	4.1 ± 0.2^{ab}	4.3 ± 0.2^{ab}

[abcde] Means within each row followed by a different letter are significantly different at $P < 0.05$.

4.2. Meat quality: general discussion

Meat tenderness as well as other eating quality attributes is a function of production, processing and the cooking method used to prepare meat. Various quality assurance systems exist of which the Meat Standards Australia grading scheme is a fine example (Thompson, 2002). Implementation of best practice genetics, pre-harvesting cattle management (e.g. hormonal growth promotants, stress, growth path), early *post-mortem* processing (chilling rate and electrical stimulation) and *post-mortem* ageing are indicated in this system as critical steps to reduce the incidence of tough beef. The effect of genetics is confined to contrasts between *Bos indicus* and *Bos taurus* genotypes. It is accepted that cattle with high *Bos indicus* content produce less tender and appears to be more variable (Crouse et al., 1989; Wheeler et al., 1990; Shackelford et al., 1991a), that the magnitude of the effect tend to vary among studies and is mainly a function of higher calpastatin activity resulting in lower rates and amount of *post-mortem* tenderization. Some studies also ascribe the *Bos indicus* effect to leaner carcasses leading to cold shortening, while other studies reported that the negative effect of higher calpastatin activity could be overcome by effective electrical stimulation that enhanced the activity of calpains in carcasses with *Bos indicus* content, thereby canceling out the negative effect (Hearnshaw et al., 1998; Ferguson, Jiang, Hearnshaw, Rymill, & Thompson, 2000). It could be argued that the limited calpain present in Brahman longissimus is probably protected with stimulation, but not in the absence of stimulation as described in the work of Rosenvold et al. (2007). They concluded that electrical stimulation will enhance tenderness even at high rigor temperatures. It therefore follows that limiting calpains such as in Brahman cattle will be degraded by high pre-rigor temperatures when not stimulated but protected when rigor mortis is reached, which occurs sooner with stimulation. Despite these results, *Bos indicus* content was included as one of the factors used to predict eating quality in the MSA cuts based grading system and hump height is used as criterion, while Wheeler et al. (2002) report on the same method.

Indigenous African cattle breeds (Sanga) were often in the past misnamed and mistaken for *Bos indicus* types due to their morphological resemblance, for example their humps. A study comparing gene frequencies of several protein polymorphisms between African, European and Indian breeds indicated that Sanga breeds had more in common with taurine than with indicus breeds (Manwell & Baker, 1980). All of the breeds belonged to the genus Bos and showed a high degree of commonality of randomly selected genes, regardless of gene flow or convergent evolution. Frisch, Drinkwater, Harrison, and Johnson (1997) using four DNA markers, protein polymorphisms and karyotype confirmed this. According to the latter study, southern African Sanga breeds have a submetracentric Y chromosome typical of *Bos taurus,* in contrast to the Boran, an East African Zebu, showing a acrocentric Y chromosome similar to the karyotype of *Bos indicus*. Furthermore, frequencies of four DNA markers and several protein polymorphisms also showed that southern African Sangas (in this study the Tuli) have more in common with taurine breeds than indicine, while East African Zebus are admixtures of African taurine and Asian indicine. In support of these findings Meyer (1984), reported that several southern African Sanga breeds have a unique haemoglobin variant HbI, the typical indicine variants HbC and albumin C are absent from Sanga and taurine breeds and that α-lactalbumin A was absent in taurine breeds and present in Sanga and Zebu. Frisch et al. (1997) suggested that southern African Sangas (Afrikaner, Nguni, Pedi) be classified as *Bos taurus sudafricanus* to distinguish them from other African taurine groups and to indicate that their ancestors were mostly of taurine origin. Likewise, the African Zebu (Boran and some Malawi Zebus), which have thoracic humps (in contrast to a cervico or cervico-thoracic humps of southern African Sanga) should be classified as *Bos taurindicus africanus*, supporting the evidence (karyotype and protein polymorphism) that African Zebu are admixtures of both Asian indicine and African taurine breeds. Therefore, on morphological evaluation (including a prominent hump), the indigenous breeds could unfairly be disqualified as having a predisposition towards tough meat. Several research projects report the opposite.

4.3. Meat quality: feedlot animals

In the following discussions, Warner Bratzler shear force was used as tenderness measurement. Although no local data exist to relate shear values to consumer satisfaction Shackelford, Morgan,

Table 3
Shear force and selected histological measurements of the *m. longissimus thoracis* of three indigenous South African breeds and three exotic cattle breeds (Strydom et al., 2000b)

	Bonsmara	Afrikaner	Nguni	Santa Gertrudis	Brown Swiss	Pinzgauer
Shear force (N/25 mm ϕ)	92.3^{a} (1.87)^{d}	95.5^{a} (4.17)	91.1^{a} (4.17)	116.4^{b} (4.17)	93.3^{a} (4.17)	101.7^{a} (4.17)
MFI 7 days *post-mortem*^{e}	108.1^{a} (2.6)	128.9^{bc} (5.6)	136.0^{c} (4.2)	111.0^{ab} (5.9)	95.9^{a} (9.9)	
Sarcomere length (μm)	1.79^{a} (0.01)	1.87^{ab} (0.03)	1.89^{b} (0.03)	1.90^{b} (0.03)	1.84^{ab} (0.03)	1.88^{ab} (0.03)
White muscle fibre area (μm^2)	5690^{ab} (163)	6241^{ab} (328)	5130^{a} (170)	9401^{c} (1521)	8578^{b} (497)	
White muscle fibre ratio: (%)	40.3^{b} (0.30)	35.4^{a} (0.63)	36.3^{a} (0.47)	43.8^{b} (0.66)	36.1^{a} (1.35)	

[abc] Means within each row followed by a different letter are significantly different at $P < 0.05$.
[d] Standard error.
[e] Myofibrillar fragmentation index.

Table 4

Warner Bratzler shear force and selected histological and biochemical properties of *m. longissimus* of various Southern African indigenous breeds and the Brahman (Strydom et al., 2008)

	Commercial Bonsmara	Emerging Bonsmara	Emerging Brahman	Commercial Drakensberger	Emerging Nguni	Communal Nguni	Tuli	s.e.
Shear force day 2 (kg)	5.24^{ab}	5.13^{a}	6.50^{d}	5.23^{ab}	6.12^{cd}	5.23^{ab}	5.54^{abc}	0.273
Shear force day 21 (kg)	3.51^{a}	3.46^{a}	4.53^{c}	3.38^{a}	4.08^{b}	3.59^{a}	3.77^{ab}	0.166
MFL (μm)^{e}day 2	39.5^{a}		45.7^{b}	37.7^{a}	38.3^{a}		43.8^{b}	1.43
Calpastatin: μ-calpain ratio	4.57^{a}		7.73^{d}	5.30^{b}	5.20^{ab}		6.00^{c}	0.245
Soluble collagen (%)	20.9^{ab}		19.7^{a}	22.6^{b}	22.6^{b}		23.4^{b}	0.980

[abcd] Means within each row followed by a different letter are significantly different at $P < 0.05$.

[e] Myofibrillar fragment length.

Cross, and Savell (1991b), reported threshold values of 4.6 and 3.9 kg for "retail" and "food service" beef, respectively. For the trials discussed below the same preparation and test method were used except for the studies of Strydom, Naudé, Scholtz, and Van Wyk (2000b) and Frylinck and Heinze (2003) where 25 mm cores instead of 12.5 mm cores were used for shear force measurement.

Strydom et al. (2000b) showed no differences between Nguni, Afrikaner and Bonsmara compared to Pinzgauer and Brown Swiss, while the loin muscle of the Santa Gertrudis was less tender after 7 days ageing (Table 3). No convincing histological or biochemical support could be found for these differences except that the Santa Gertrudis tended to have proportionally more and larger white muscle fibers, while those of the Nguni and Afrikaner were smaller and less abundant. Furthermore, the myofibrillar index at 7 days *post-mortem* was the highest for the Nguni followed by the Afrikaner indicating favourable progress in proteolysis. Various studies reported negative relationships between fiber size (or particular white fiber) and white fiber proportion and tenderness (Calkins, Dutson, Smith, Carpenter, & Davis, 1981; Crouse, Koohmaraie, & Seideman, 1991). In the study of Strydom et al. (2008) where indigenous breeds and Brahman from different farming systems (commercial, emerging and communal) were compared, the variation among indigenous breeds was small especially with prolonged ageing (21 days), while Brahman produce consistently tougher loins independent of duration of ageing (2 or 21 days) (Table 4). In further tests not reported in this publication, the Brahman showed significantly lower proportions of soluble collagen, higher calpastatin:μ-calpain ratios and longer myofibril lengths at 2 days *post-mortem* compared to the indigenous breeds (except for the Tuli). Frylinck and Heinze (2003) also reported consistently lower shear force values for Bonsmara, Afrikaner and Nguni (all Sanga types) loins compared to Brahman loins at 1, 3, 7, 14 and 21 days *post-mortem* (Fig. 1). Hereford loins were similar in tenderness to Sanga loins, while Simmental loins showed similar shear values to those of Brahman. In agreement with Strydom et al. (2008), contrasts in shear values between Brahman and Sanga coincided with significant differences ($P < 0.05$) in calpastatin: μ-calpain ratios at one and 24 h *post-mortem* (Fig. 2). However, variation in calpastatin: μ-calpain ratios did not explain the higher shear values for Simmental loins and neither did measurements for sarcomere length, myofibril length and collagen solubility give convincing evidence for the tenderness differences among breeds in general. From results of the same study Taylor and Frylinck (2003), found that muscle fiber to fiber detachment and breaks across the diameter of the fiber were events that related to tenderness. Due to the limited number of animals per breed ($n = 3$) used for structure measurements, a clear breed effect was absent, but breed by ageing effect was significant for fiber detachment and fiber breaks. In this regard, Brahman showed less ($P < 0.05$) fiber detachments than the other breeds at 21 days *post-mortem* and Brahman and Simmentaler had fewer fiber breaks ($P < 0.05$) at 7 days *post-mortem* compared to the other breeds.

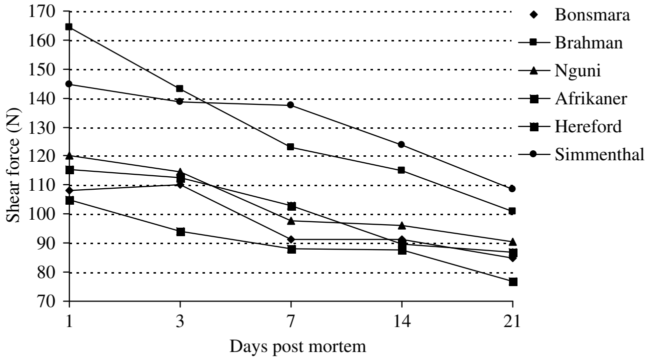

Fig. 1. Influence of ageing period on Warner Bratzler shear force tenderness of *m. longissimus* of South African indigenous and foreign beef breeds (Frylinck & Heinze, 2003).

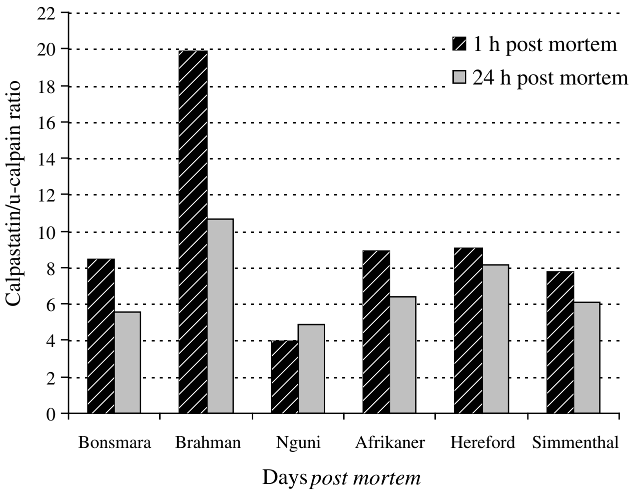

Fig. 2. Calpastatin/μ-calpain ratio in the *M. longissimus* of South African indigenous and foreign beef breeds at one and 24 h *post-mortem* (Frylinck & Heinze, 2003).

Despite the small size combined with the relative leanness of the Nguni and Afrikaner carcasses in the studies discussed above, toughening due to cold-shortening of the muscle as a result of rapid chilling was effectively prevented by electrical stimulation. Collectively, the studies showed that indigenous South African breeds (Sanga) compared favourably to exotic breeds from Europe and produced more tender meat than indicus breeds under ideal slaughter conditions. The mechanisms for the favourable expression of meat tenderness in Sanga breeds are not exactly clear but seems too be related to the action of the muscle proteinase system, which seems to be limited for the Brahman.

4.4. Meat quality: Pasture animals

Du Plessis and Hoffman (2007) reported no differences for sensory attributes (flavour, juiciness, tenderness) or shear force resistance of three days aged loin muscle from Nguni, Brahman and Simmental crosses aged between 18 and 30 months. Relatively large carcass weight and fatness differences occurred between the Nguni and Simmental crosses, yet under proper commercial slaughter conditions (which included electrical stimulation) the effect of possible variation in chilling rate on muscle contraction was overcome and the effect of the higher age of the animals compared to feedlot animals did not differentiate among breeds. Under similar commercial slaughter conditions, but much poorer grazing conditions, which resulted in very small and lean carcasses Muchenje et al. (2008), also found no differences in tenderness among Nguni, Bonsmara and Angus.

4.5. Interaction of breed, pre-slaughter and immediate post-mortem procedures on quality

In the crossbreeding trial reported by Strydom and Frylinck (2005), the effects of electrical stimulation (0, 15 and 120 s high voltage) and feed withdrawal time had far more significant effects on tenderness than breed type, in particular for unaged loins (1 days *post-mortem*). Nevertheless, the loins from Nguni cross carcasses were more tender than those from Simmental crosses at both 1 and 14 days *post- mortem*, which coincided with higher collagen solubility, lower calpastatin: μ-calpain ratios and shorter myofibrillar fibre lengths (biochemistry not published yet).

Despite the favourable tenderness values, Nguni cross loins had marginally higher final pH values ($P < 0.05$) than the other two crosses (Brahman and Simmental) especially when longer feed withdrawal periods were applied (Interaction: $P < 0.05$; Fig. 3). In addition, their sarcomere lengths were significantly shorter ($P < 0.05$) but not influenced by feed withdrawal or stimulation treatment (Table 5). Purchas and Yan (1997) and Purchas, Yan, and Hartley (1999) showed that beef with final pH values ranging closely around 6 were often tougher and their sarcomeres shortened. In contrast Watanabe, Daly, and Devine (1996), reported that intermediate high pH values mainly affected tenderness negatively early *post-mortem* (one day) and had almost no effect after five days *post-mortem* in sheep meat. Furthermore Devine et al. (2006), reported that even at ultimate pH values above 5.7, electrical stimulation still contributed significantly to tenderness development, which concur with the situation for Nguni in the present study. From the same project O'Neill, Webb, Frylinck, and Strydom (2006), showed that the higher tendency for ultimate pH of the Nguni coincided with higher levels of urinary catecholamines, epinephrine and nor-epinephrine. In addition, significantly lower L^* and chroma values indicated darker meat for Nguni crosses (Strydom, unpublished data). Collectively, this data suggest that Nguni in these trials was more susceptible to pre-slaughter stress, while the intensity of its reaction was not such that it influenced meat tenderness significantly, at least not in comparison with the other two breed groups in the trial. Muchenje et al. (2008) also reported lower light reflection (L^*) values for pasture fed Nguni compared to Bonsmara and Angus, while Du Plessis and Hoffman (2007) and Strydom et al. (2008) found no differences in pH or colour attributes for pasture and feedlot Nguni compared to other breeds and crosses that included Brahman.

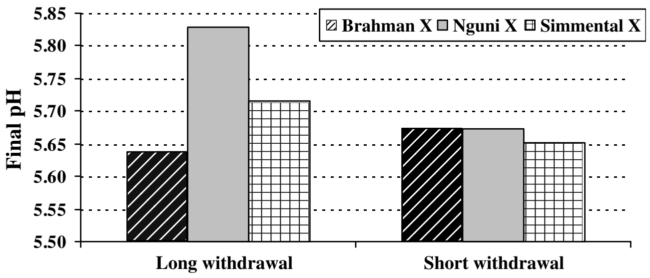

Fig. 3. Interaction between breed and feed withdrawal period regard to final pH (Unpublished data).

Table 5
Warner Bratzler shear force and selected histological, physical and biochemical properties of *m. longissimus* of Brahman, Simmental and Nguni crosses (Strydom & Frylinck, 2005; O'Neill et al., 2006 and unpublished data)

Breed	Brahman	Nguni	Simmental	SEM^2
Shear force day 2 (kg)	6.9^{ab}	6.7^{a}	7.3^{b}	0.1627
Shear force day 14 (kg)	4.3^{a}	4.4^{a}	4.9^{b}	0.1266
Sarcomere length (μm)	1.72^{b}	1.65^{a}	1.70^{b}	0.0152
MFL day 7 (μm)^{d}	34.1^{b}	31.3^{a}	33.4^{ab}	0.841
% Collagen solubility	17.92^{a}	19.31^{b}	17.47^{a}	0.438
Calpastatin: μ-calpain ratio	1.68^{c}	1.36^{a}	1.51^{b}	0.0.498
CIE Lab:				
$^*L$ – lightness	39.0^{b}	36.9^{a}	37.8^{a}	0.325
Chroma	18.3^{b}	16.3^{a}	17.8^{b}	0.276
Urinary catecholamines ratios:				
Nor-epinephrine: creatine	3.23^{a}	4.10^{b}	2.98^{a}	0.278
Epinephrine:creatine	1.56^{a}	2.77^{b}	1.71^{a}	0.178

[abc] Means within each row followed by a different letter are significantly different at $P < 0.05$.

[d] Myofibrillar fragment length.

4.6. Quantitative genetics and meat quality of indigenous cattle breeds

While sufficient evidence exist that variation in tenderness among breeds is significantly related to the percentage of *Bos indicus*, within breed variation in tenderness is believed to be more than variation between breeds (Koohmaraie, Veiseth, Kent, Schackelford, & Wheeler, 2003). Genetic approaches such as the use of candidate genes or gene mapping (quantitative trait loci and marker assisted selection) instead of progeny testing is a fairly new field of development of non-invasive techniques to select animals with potential for superior quality meat. When measures are taken to prevent cold shortening, proteolysis is considered to be one of the main factors influencing the variability in beef tenderness (Koohmaraie, 1996). In particular, the calpain enzymatic system is involved in this process with both μ-calpain and *m*-calpain playing significant roles and calpastatin acting as inhibitor of these two enzymes (Koohmaraie, 1996; Hopkins & Thompson, 2001). Therefore most of the meat quality gene technology revolves around markers for either the μ-calpain, encoded as CAPN1 gene or calpastatin encoded as CAST gene (Koohmaraie, 1996). At the moment GeneSTAR (registered trademark of Genetic Solutions Pty Ltd.) tests for four tenderness related DNA markers (Anonymous, 2008a). In 2004, DNA of 143 representative South African indigenous cattle breed sires was tested for the tenderness related gene marker (TEND1). Selection of sires was based on identifying unrelated sires with the largest number of performance recorded progeny within each breed. Of five indigenous breeds represented, the Afrikaner had the highest frequency the tenderness related gene (97%), followed by the Bonsmara (94%), Drakensberger (82%), Nguni (81%) and Tuli (61%) (Banga & Van der Westhuizen, 2004). Although it is accepted that other genes influencing tenderness also exist, of which some have been identified since 2004, the results are a strong suggestion of the natural occurrence of quality related genes in these breeds. Since 2002, 3000 animals from Brahman, Simbra, Brangus and Simmental (at least 60 animals per breed) taking part in Breedplan International Beef Recording

Scheme were tested for TEND1 gene frequencies and their respective frequencies were 63%, 71%, 82% and 77% (Anonymous, 2008b). Finally, in a group of commercially bred Brahman, Simmental and Nguni cross bulls Marais (2007), showed that the Nguni crosses had a higher average index (6.62) for favourable combinations of the CAST and CAPN1 gene as reported by White et al. (2005) and Casas et al. (2006), than the Brahman (8.11) and Simmental crosses (7.74). The relationship between the gene frequencies and meat quality characteristics has not been published yet.

5. Conclusions

Results from various trials indicate that variation among the indigenous breeds enable producers in the different production systems to select and utilize indigenous animals that are suitable to their specific circumstances to produce quality beef economically. Variation in frame size among indigenous breeds will determine their suitability as feedlot cattle depending on the price and feed margins driving profit in this industry sector. Meat quality analyses indicate small or no differences between indigenous and exotic European/British breeds and potentially superior quality compared to *Bos indicus* breeds. Random tests for tenderness related gene markers confirm the presence of high frequencies of favourable genes in indigenous breeds, which support their meat quality potential.

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