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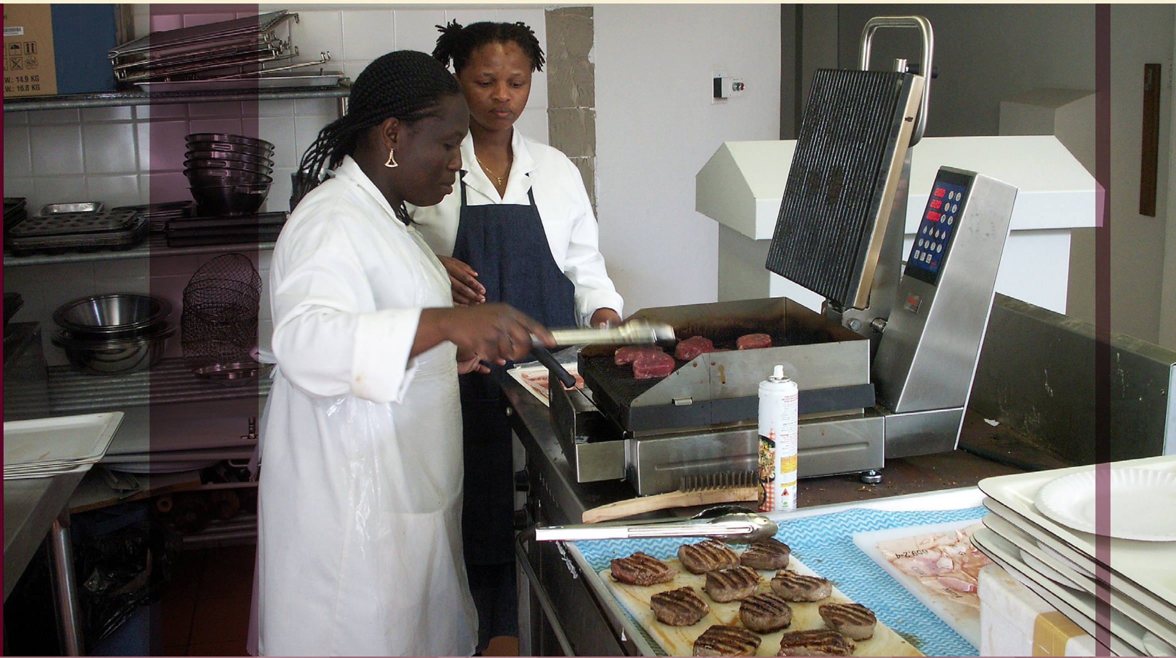

Beef palatability in the Republic of South Africa: implications for niche-marketing strategies

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John Thompson, Rod Polkinghorne, Alan Gee, Dan Motiang, Phillip Strydom,
Mpho Mashau, Jones Ng'ambi, Rietta deKock and Heather Burrow

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GPO Box 1571, Canberra ACT 2601, Australia
Telephone: 61 2 6217 0500
<aciar@aciar.gov.au>

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Cover: Preparing samples of grilled beef for a taste panel. Photo by Alan Gee.

Foreword

Smallholder cattle farmers in the Republic of South Africa manage an estimated 5 million head of cattle on communal or privately owned grazing land. In the past, they could sell their cattle as steers or old cows for reasonable prices. The advent of a large feedlot sector, however, has meant that the commercial market now requires animals that are earlier maturing, efficient converters of high-quality feed and possess superior carcass attributes. Indigenous cattle being sold by smallholder farmers are not currently meeting the feedlot entry specifications for weight, fatness, age and frame score. As a result, the South African beef market is dominated by grain-fed beef, with commercially oriented feedlots supplying 75% of the beef that reaches retail shelves.

The Australian Centre for International Agricultural Research (ACIAR) has supported research on improving the competitiveness and profitability of smallholder cattle producers in South Africa since 1992. Earlier research demonstrated that it is possible for indigenous cattle to achieve the entry specifications of the feedlots. There is, however, a widely held assumption that the major consumer demand in South Africa is for grain-fed beef from non-indigenous breeds. The consumer research presented in this report highlights the potential for smallholder producers of indigenous cattle to gain a share of markets currently dominated by grain-fed beef from feedlots.

Nick Austin
Chief Executive Officer, ACIAR

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Authors' contact addresses

John Thompson, CRC for Beef Genetic Technologies, C.J. Hawkins Homestead, University of New England, Armidale, New South Wales 2351, Australia
Email: jthompso@une.edu.au

Rod Polkinghorne, Marrinya Pty Ltd, Vilgilates Road, Wuk Wuk 3875, Victoria, Australia
Email: Rod.Polkinghorne@gmail.com

Alan Gee, Cosign Pty Ltd, 20 Eleventh Avenue, Sawtell, New South Wales 2452, Australia
Email: alphageemale@gmail.com

Dan Motiang, Agricultural Research Council – Animal Production Institute, Private Bag X2, Irene 0062, Republic of South Africa
Email: dan@arc.agric.za

Phillip Strydom, Food Science and Technology: Meat Science Unit, Agricultural Research Council – Animal Production Institute, Private Bag X2, Irene 0062, Republic of South Africa
Email: pstrydom@arc.agric.za

Mpho Mashau, Department of Animal Science, School of Agriculture and Environmental Sciences, University of Venda, Thohoyandou, Republic of South Africa
Email: mpho.mashau@univen.ac.za.

Jones Ng'ambi, Department of Animal Production, School of Agriculture and Environmental Sciences, University of Limpopo, Polokwane, Republic of South Africa
Email: jonen@ul.ac.za

Rietta deKock, Department of Food Science, University of Pretoria, Pretoria, Republic of South Africa
Email: riette.dekock@up.ac.za

Heather Burrow, CRC for Beef Genetic Technologies, C.J. Hawkins Homestead, University of New England, Armidale, New South Wales 2351, Australia
Email: heather.burrow@une.edu.au

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Summary

The beef industry in the Republic of South Africa (RSA) is mostly based on heifers and steers that are placed in a feedlot soon after weaning, for slaughter as yearling animals. During the finishing phase they generally receive one or more hormonal growth implants (HGP). This contrasts to the system for indigenous breeds for which generally only entire males ranging in age up to 10 years are available for slaughter. The bulls are finished on pasture without any HGP implants. While these older indigenous bulls would be expected to be tougher because of sex and age effects, given they do not receive any HGPs might mean that the differences in eating quality between the two groups of animals are less than expected. A relevant commercial comparison in terms of eating quality would be between young steers or heifers finished in a feedlot with one or more HGPs and older indigenous bulls left entire and with no HGPs.

Urban consumers in RSA currently demand beef from young feedlot-finished carcasses, which they grill. In contrast, the rural consumers use cuts high in connective tissue and prepare them using traditional slow-cooking methods. While the increased connective tissue toughness from older carcasses would generally be a problem with grilling, it may not be if the meat is cooked slowly as a stew. It may be that cuts from the older, lighter, indigenous pasture-finished bull carcasses are better suited to rural consumers, offering a potential niche market.

The work described in this report examined the sensory responses of rural and urban RSA consumers tasting high and low connective tissue muscle prepared as a grill or slow cooked. The carcasses used to provide taste panel samples were sourced from two suppliers in RSA and one in Australia. The Australian samples were sensory tested using Australian consumers and exported to RSA to be tasted by consumer groups there, to provide links back into the Meat Standards Australia (MSA) database. The RSA cattle groups comprised 18 older pasture-finished Nguni bulls and 18 young feedlot-finished Bonsmara steers. The Australian cattle comprised 18 two-tooth pasture-finished Murray Grey steers that had not received HGPs. Taste panel samples were collected from high connective (blade, chuck and topside) and low connective tissue (striploin) cuts from both RSA and Australian carcasses. There were 360 urban and 360 rural RSA consumers in the taste panels, which tested both grilling and slow-cooking methods. RSA urban consumers were sourced from Pretoria and the rural consumers from townships and villages surrounding Limpopo and Venda universities. The Australian samples were tasted as grills only, using 540 Australian consumers largely sourced from Sydney suburbs.

Demographic details were recorded before each tasting session. Consumers were asked to score samples for tenderness, juiciness, liking of flavour and overall liking. They were then asked to grade the sample into one of the following four grades; unsatisfactory (2 star), good everyday (3 star), better than everyday (4 star) and premium (5 star). After the taste panel was completed, consumers were asked what they would pay for the beef they had rated as 2, 3, 4 or 5 star.

The demographics of the consumer groups showed both rural and urban RSA were younger than those sampled for Australian taste panels. Sexes were evenly balanced within all groups. While students made up about one-third of the rural consumers, they comprised less than 13% of the urban consumers and less than 1% of the Australian consumers. The numbers of adults in the household were similar between rural and urban samples in RSA. As expected, the RSA rural consumers had a higher proportion of panelists in the low-income categories than had the urban consumers. The RSA rural consumers ate meat less frequently than the urban consumers, whereas the RSA urban and Australian consumers had similar meat-consumption patterns. As all panelists had volunteered for the taste panel it was not surprising they all considered meat an important part of their diet. Both urban and rural RSA consumers preferred their meat to be

cooked medium to well done, or well done. Australian consumers preferred their meat medium/rare or medium/well done.

The Nguni bull carcasses from RSA were extremely lean. The ultimate pH for this group of carcasses was very high, with only one carcass having an ultimate pH of less than 5.7. Consistent with this high ultimate pH, the Nguni carcasses had very high meat-colour scores with a mean score of about 5. The Bonsmara carcasses from RSA were much heavier than the Nguni bulls and were also fatter. The Bonsmara steers had an extremely rapid pH decline with a mean temperature at pH6 of 41˚C, possibly due to excessive stimulation. They had a low ultimate pH, with all carcasses reading less than 5.7. In keeping with their low ultimate pH, the Bonsmara carcasses had a low meat-colour score. The Murray grey cattle slaughtered in Australia were the heaviest group of cattle. They had low ultimate pH readings (all less than 5.7) and similar meat-colour scores to the Bonsmara carcasses, indicating adequate glycogen reserves in both those groups before slaughter.

The relationship between sensory scores and the allocated grades (2, 3 4 and 5 star) showed there were only subtle differences both between rural and urban consumers in RSA and also between RSA and Australian consumers. Cooking method had little effect on the assessments of RSA urban and rural consumers. The boundaries between grades varied slightly between consumer groups, with rural RSA consumers having a lower threshold for defining 5-star product than had urban RSA and Australian consumer groups. The accuracy of using a fixed weighting to combine sensory scores into a composite palatability score (MQ4) to allocate samples to the different grades was high enough in all consumer groups to support a quality description system based on sensory scores.

Correlations between the different sensory traits were generally high, with no difference between the RSA consumer groups and Australian consumers. Except for the Australian data, the lowest correlations were between juiciness scores and tenderness and flavour scores.

For the blade samples, the Nguni beef had an eating quality score of 43, compared with about 60 for blade samples from the Bonsmara and Murray Grey carcasses. For the chuck samples, urban consumers gave higher scores than rural consumers, whereas there was no difference between consumer groups for the striploin samples from Bonsmara or Murray Grey carcasses. It was suggested that some of the differences between suppliers could have reflected the extremes in the rate of glycolysis and ultimate pH.

There was a carcass side interaction on sensory scores for the striploin in Nguni carcasses, whereby samples from the side suspended during processing were tougher than the unrestrained leg. It was suggested the low glycogen levels in the Nguni carcasses allowed carcasses to go into rigor while suspended by the left leg and hence produced tougher meat in the restrained leg. The right leg was not suspended and so was effectively tender-stretched as it went through rigor.

A direct comparison of just the grilling data for the blade, chuck and striploin samples from Australian carcasses showed that when the different consumer groups ate the same muscles from the same carcasses, RSA consumers gave scores that were 2 to 12 points higher than the scores given by Australian consumers for the same samples. In other words, the RSA and Australian consumers' perceptions of eating quality differed.

The willingness-to pay (WTP) data showed that both rural and urban consumers were willing to pay more for higher quality beef. The increase in WTP relative to 3 star was about half again for 4 star and twice for 5 star. Few demographic factors affected WTP and there was no difference between urban and rural RSA consumers. In alignment with the published literature, both the RSA and Australian consumers showed that younger consumers were willing to pay more for quality than were older consumers. The consistency of this interaction between different countries (RSA, Australia, Japan, Ireland and the USA) suggests that despite large differences in cultural background and income, this behaviour is innate in consumers, even although the younger consumers have, in many instances, less money to purchase higher priced goods and services.

It is recommended that the extremes in carcass processing in RSA be considered as part of any future study to confirm that acceptable meat can be produced from pasture-finished Nguni bulls when they are delivered to slaughter with adequate reserves of glycogen and after the carcasses have received the optimal amount of electrical stimulation. This could be used as a training exercise to embed consumer taste panels as a tool to monitor eating quality in any subsequent supply chain program. Implicit in this recommendation is that the consumer sensory protocol be adopted as a tool of preference to establish the relationships between animal production, processing and value-adding treatments and, ultimately, consumer satisfaction. The strong relationship between WTP data and assessed eating quality indicates that industry efforts to improve eating quality have the potential to generate considerable additional revenue (i.e. there is capacity to charge a higher price for higher quality meat).

This study clearly showed that sensory scores from both urban and rural consumers did not differ substantially. Both urban and rural groups indicated similar WTP for meat quality. Future work in this area could therefore investigate all avenues to improve meat quality from indigenous breeds. It seems clear that by ensuring no implants are used and that carcasses are processed under optimal conditions (i.e. there are good glycogen reserves at slaughter and the carcasses have been given optimal electrical stimulation) good quality meat can be obtained from older Nguni bulls. Other research—see, for example, the papers in Thompson et al. (2008a)—has shown that interventions such as tenderstretch, extended ageing, portioning of muscle and matching the optimal cooking styles to particular cuts of beef, could also be used to improve eating quality and capture market share for a supply chain based on indigenous breeds.

Background

Achieving improvements in profitability and long-term viability of the emerging beef sector in South Africa has been identified as a national priority. While cattle are an important asset in South Africa's poor rural communities and comprise 40% of South Africa's 13 million head of cattle, they currently contribute only 5% to South Africa's GDP.

Returns to the producer are directly linked to beef demand determined by the relationship of price and quality. An understanding of consumer sensory perception of beef quality, and of the linkage of quality to price, is an important foundation for developing programs that can build demand and improve returns.

The South African beef market is currently dominated by grain-fed beef, with feedlots supplying 75% of beef that reaches retail shelves. Indigenous cattle breeds being sold by emerging and communal farmers are not meeting the current feedlot induction specifications for weight, fatness, age, frame score and sex. A previous study (Strydom et al. 2008) demonstrated that it was possible for these cattle to achieve the specifications for the South African feedlots, but the systems needed to do this have not been generally available to emerging and communal farmers. Nevertheless, indigenous cattle are generally well-adapted to their often harsh and variable environment and, as demonstrated by the earlier studies, they can achieve a reasonable slaughter weight if carried through for several seasons.

Under the commercial feedlotting system employed in South Africa most males are castrated. Soon after weaning, both females and males are inducted into the feedlots. Steers and heifers finished in the feedlots are given one or more hormonal growth implants (HGPs) during the finishing phase, sometimes followed by a Zilpaterol supplement several weeks before slaughter. In contrast the indigenous males are left entire and are sometimes 8 or 10 years old before they reach marketable weights. A meta-analysis of published results on the effect of HGP implantation on objective and sensory meat quality concluded that HGPs resulted in an increase in toughness of the striploin (Watson 2008). HGPs are not used by emerging farmers. Therefore, while the meat from their older animals might be expected to be tougher because of sex and age effects, the fact that the animals are not implanted with HGPs may mean that the differences in eating quality between carcasses produced under the RSA feedlot system and those of indigenous cattle grown out on pasture by the rural farmers are less than expected.

Previous studies rightly compared animals under the same management systems and detected little difference in eating quality when all breeds were processed under the South African feedlotting system (e.g. Strydom et al. 2008). However, the relevant commercial comparison would be between young steers or heifers with one or more HGP implants, finished in a feedlot, and older indigenous bulls with no HGP implants. The eating quality of carcasses produced from these two contrasting management systems has not been compared. There are also few direct consumer data available, most experiments being evaluated by objective laboratory techniques.

Currently, the assumption is that consumer demand in RSA is for young feedlot-finished carcasses. Cuts from these carcasses, low in connective tissue, would generally be grilled. In contrast, many rural communities traditionally use various forms of wet cooking. The South African consensus is that the traditional wet cooking places a greater emphasis on beef flavour than on tenderness. While the increased connective tissue toughness from older carcasses would generally be a problem with grilling, it may not be so if a slow-cooking method that solubilises the collagen is used. If this were the case it may be possible to develop a niche market using beef from older, lighter, pasture-finished bull carcasses from breeds such as the Nguni, to substitute for beef from the steers and heifers currently produced from the feedlot system in South Africa.

The Meat Standards Australia (MSA) program has investigated consumer segmentation in domestic and international beef markets. Previous studies with Australian, Korean, Japanese, US and Irish consumers have focused on grilling and other cooking methods that reflect the traditional forms of cooking in the various markets (Thompson et al. 2008b; Hwang et al. 2008; R. Polkinghorne, unpublished data). Both tenderness and flavour were found to be important contributors to consumer satisfaction in these studies (Watson et al. 2008; Polkinghorne 2006). Over recent years, flavour has been rated equal to tenderness in several trials, including those that studied shabu shabu and yakiniku cooked product. However, all the forms of cooking used in these studies (grilling, Korean BBQ, roasting, stir-frying, shabu shabu and yakiniku) focused on low heat and/or short cooking times that would not be expected to solubilise connective tissue. A slow, wet-cooking method, as used in traditional RSA slow cooking, may identify market segmentation that places a larger emphasis on flavour and less on tenderness than are suggested by the current RSA market specifications. Whether or not this is so cannot be evaluated without knowledge of consumer sensory responses.

The study reported here had several aims. First, it examined sensory responses of rural and urban RSA consumers and the potential to niche-market beef to rural consumers in RSA. Second, a paired set of samples was tested by both RSA and Australian consumers to provide links back into the Australian MSA database. This information should allow beef products from South Africa to be rated for acceptability to different markets and consumer groups around the world.

Materials and methods

Experimental design

The experimental design comprised taste panels undertaken in RSA utilising rural and urban consumers who tested a mixture of RSA and Australian beef samples from cuts high and low in connective tissue, prepared by grilling and slow-cooking methods. Linked to this, the Australian samples were also tested as grills, using Australian consumers. A full crossover design where RSA samples were also tested using Australian consumers was not possible, as RSA samples could not be imported into Australia.

The RSA taste panels comprised 720 South African consumers who were sourced from rural (360) and urban (360) regions, tasting meat samples from both RSA and Australian cattle suppliers. The samples were cooked by grilling and slow-cooking methods. The matching Australian samples were grilled and served to 540 Australian consumers as part of ongoing taste panels being conducted in Australia.

Muscle samples were prepared from high (blade, chuck and topside) and low (striploin) connective tissue cuts derived from three cattle suppliers. The RSA samples were sourced from two suppliers, the first providing 18 young (all milk teeth) Bonsmara steers from a commercial feedlot. The steers had been given two hormonal growth implants (HGP) and had been grain fed from 108 to 132 days. The second RSA supplier provided 18 pasture-fed Nguni bulls that ranged from 2 to 8 teeth and had not received HGP implants. The Australian cattle were 18 pasture-fed, unimplanted Murray Grey steers.

Slaughter

Murray Grey

The steers were slaughtered at the Co-operative Meatworks at Casino, New South Wales. The cattle were mustered off grass and trucked approximately 400 km to the abattoir. Animals were slaughtered the day after arriving at the abattoir and the carcasses stimulated using a high-voltage system before evisceration. Carcass sides were placed in a chiller, and pH, temperature and time measured in the *m. longissimus dorsi* at the 12/13th rib junction at approximately hourly intervals for the first 6–8 hours after slaughter. On the following day, carcasses were MSA graded and chilled over a weekend before boning. MSA grading comprised measurement of 12/13th rib fat, USDA ossification and marbling scores (Romans et al. 1994) and AUS-MEAT meat colour (Anon. 1992) as well as ultimate pH and temperature. To convert the AUS-MEAT meat colour score to a numeric scale, 1B scores were assumed to be equal to 1.33 and 1C to 1.67.

At boning, both sides of the Murray Grey carcasses were boned to provide a total of nine muscles or muscle portions: *m. triceps brachii* (BLD096), *m. serratus ventralis* (CHK078), *m. biceps femoris* (OUT005), *m. supraspinatus* (OYS036), *m. gluteus medius* (RMP131 and RMP231 muscles), *m. longissimus dorsi* (STR045), *m. poas major* (TDR062) and *m. semimembranosus* (TOP073). The primals were trimmed and prepared as steaks for grilling or cubes for slow cooking, following MSA protocols as described by Gee et al. (2005). Sample position within muscle and carcass side was rotated to balance cooking method by country of testing. The RSA experiment used only the BLD096, CHK078, STR045 and TOP073 samples, which had been aged for 5 days. The remaining samples were used as part of an extended aging experiment in Australia, a collaborative study with INRA in France to compare French and Australian consumers, and finally a collaborative study with Texas Tech in the USA to develop a methodology to quantify beef flavour.

Bonsmara and Nguni cattle

The suppliers of these animals provided 18 Bonsmara steers from the Chalmar feedlot and 18 pasture-fed Nguni bulls from the Agricultural Research Council research station located 120 km from the abattoir. Figures 1 and 2 show the cattle in the forcing pen just before slaughter. The Bonsmara steers were taken off feed the day before slaughter and walked from the feedlot to the abattoir. The Nguni bulls grazed natural pasture and were mustered the day before slaughter and transported to the abattoir. Animals were stunned using a captive bolt, and the carcasses stimulated using a low-voltage system for 48 seconds before being placed in the chiller. Figure 3 shows the Bonsmara and Nguni carcasses at the abattoir. The following morning, carcasses were quartered and graded by a qualified MSA grader recording the same measurements as for the Murray Grey carcasses. At boning the following day, the striploins were removed from both sides of the Bonsmara carcasses. Both the Bonsmara striploins and forequarters, together with both sides from the Nguni bull carcasses, were transported to the meat laboratory at Irene for sample preparation.

Calculation of glycolytic rate

For individual carcasses from the three suppliers changes in both pH and temperature as functions of time were modelled in individual carcasses using the exponential function

$$y_t = a_u + (a_i - a_u)e^{-kt} \qquad (1)$$

where y_t is pH or temperature at time t; a_u is ultimate pH or temperature; a_i is initial pH, or temperature; k is the exponential rate of pH or temperature fall; t is

Figure 1. Nguni cattle in the forcing pen box before slaughter

Figure 2. Bonsmara cattle in the forcing pen before slaughter

Figure 3. Bonsmara (left) and Nguni (right) carcasses at the RSA abattoir

time post-mortem. This equation was fitted using PROC NLIN (SAS 1997). Parameters from the pH/time equation were used to predict the time to achieve pH 6.0, which was then used in the temperature/time equation to predict temperature at pH 6.0 (temp@pH6).

Sample preparation

The blade (BLD096), chuck (CHK078) and striploin (STR045) primals were boned from both the Bonsmara and Nguni carcasses. Due to the small carcass weight of some Nguni cattle it was also necessary to sample the topside (TOP073) from nine Nguni carcasses to produce enough samples for the taste panels at Limpopo, Venda and Pretoria. The *m. longissimus thoracicus* (CUB045) from the Bonsmara carcasses was also prepared to use as the link, or starter sample, for each of the RSA consumer tests. All Australian samples tested by South African consumers were aged for 5 days before freezing, whereas all RSA samples were aged for 4 days.

The primals were trimmed of all epimysium and fat, yielding a block of muscle, and five steaks (each 25 mm thick) were cut from the block for grilling samples. The slow-cooked samples from each muscle were prepared as sets of 22 cubes (21 × 21 × 21 mm). Both grilled and slow-cooked samples were wrapped in plastic and frozen before preparing the taste panel picks.

Following MSA procedure, the taste panels were arranged as 12 picks, a pick comprising a set of samples served to 60 consumers. The 12 pick designs for the taste panels undertaken in the RSA were laid out using MSA AUSBlue software, which balanced the picks for country, supplier, cooking method and cut. The design specified six products, one sample of each being served to each consumer. One product was created from Nguni BLD096, CHK078 and TOP073, another from Bonsmara BLD096 and CHK078 and a third from Murray Grey BLD096 and CHK078. The remaining three products were drawn from STR045 from Nguni, Bonsmara and Murray Grey carcasses.

The RSA design created paired picks in which rural and urban consumers were presented with steaks and cubes derived from common carcasses. Using the pick designs, the frozen samples for the taste panel were laid out in serving order rounds for transport to the testing sites and later thawing and cooking.

The Australian samples were prepared under the supervision of the Australian Quarantine and Inspection Service. The high demand for samples from the Australian carcasses meant that the samples prepared from the blade and chuck (BLD096 and CHK078) were a composite of left and right sides. The striploin and topside muscles were large enough to retain side identity for the STR045 and TOP073 samples.

Cooking methods

The procedures used in the taste-panel sessions have been described in detail by Gee et al. (2005) and Watson et al. (2008). In both RSA and Australia, the samples for taste panels were transported frozen to the venue and thawed over 24 hours immediately before the tasting.

Steaks were cooked on a Silex® clam-shell grilling unit set at 220–230˚C. After cooking steaks were transferred to a cutting board, rested and halved before serving warm on pre-numbered paper plates. Figure 4 shows the samples being prepared using the Silex griller in RSA.

The cubes for slow cooking were thawed the day before testing then browned in a stainless steel frypan for 90 seconds with 30 mL of sunflower oil. They were then transferred to 1/9-size bain marie steamer pans containing 300 mL of broth and held at a rolling boil for 2 hours. The broth was made from 14 L of water to which was added 1,400 g of frozen diced carrot, 1,400 g of frozen potato chips, 470 g of frozen diced onion and 70 g of salt. The mixture was brought to the boil and held at a rolling boil for 45 minutes before transfer to the bain marie pans. Figure 5 shows serving of the slow-cooked samples from the bain maries.

Consumer recruitment

RSA consumers

The University of Limpopo recruited 180 rural tasters from local suburbs and villages, and the University of Venda a further 180. Buses were provided to transport consumers to and from the tasting venues. For the testing at the University of Pretoria, 360 urban consumers were recruited from various suburbs of Pretoria by using the university staff network. Each taste panel required 60 tasters to present themselves for tastings in three groups of 20 at pre-agreed times.

Australian consumers

The paired Australian samples were tested as grills mixed with other samples and the tests conducted in both Toowoomba and Sydney. In Toowoomba, consumers were beef-conference delegates who had volunteered to participate in the taste panel. In Sydney, consumers were contacted via clubs and community organisations, with the clubs receiving a donation for their participation. For BLD096, CHK078, STR045 and TOP073 samples aged 5 days there were only two samples tested at the beef conference compared with 16 in Sydney, so it was not possible to usefully partition the Australian consumers into conference delegates and city consumer subgroups.

Sensory testing

Sensory testing for the different cooking methods was run as separate tasting sessions using different consumers. Immediately before the sensory test, consumers were asked to fill out a questionnaire on their demographics and meat-eating habits. The questionnaire and tasting sheets used in RSA are shown in Appendix 1.

Before tasting the samples the consumers were given a brief talk on how to fill out the taste-panel sheets. For both cooking methods, the seven samples (comprising one starter sample and six experimental samples) were delivered to consumers as single samples over a 45-minute session. After resting and halving, the grilled samples were placed on pre-numbered plates and served to consumers. For the slow-cooked samples, two cubes were removed from the steamer pans, shaken dry and served on a paper plate to consumers. Consumers were asked to score samples using a 100 mm line scale for tenderness, juiciness, liking of flavour (hereinafter referred to as 'flavour') and overall liking. In addition, consumers were asked to grade the sample by indicating, by tick box, if they consid-

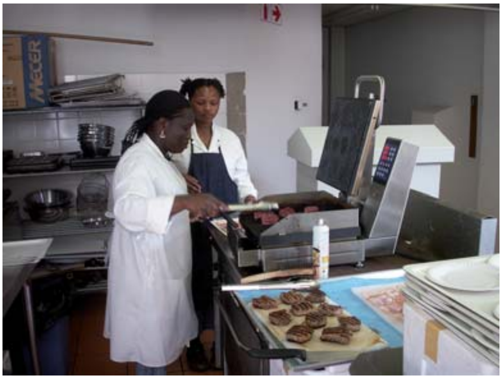

Figure 4. The grilled samples being cooked on the Silex® griller

Figure 6. A taste panel in progress in RSA

Figure 5. The slow-cooked samples being served onto plates to deliver to panelists. The bain maries were used for slow cooking beef cubes for the taste panels and for holding at the beef at serving temperature during testing.

ered the sample to be ‘unsatisfactory’ (2 star), ‘good everyday’ (3 star), ‘better than everyday’ (4 star) or ‘premium’ (5 star). Figure 6 shows the RSA consumers at Limpopo participating in a taste panel.

After tasting the seven samples, consumers were asked to complete a willingness-to-pay (WTP) survey form. For RSA consumers this form asked how much they would be willing to pay in Rand/kg ‘based upon beef they had just consumed’ for each of the four grades (i.e. 2, 3, 4 and 5 star). At the request of the RSA researchers a question on the home language of the participants was asked (see Appendix 1). For Australian consumers a similar form asked how much they would be willing to pay for each of the four grades in A$/kg. The question on home language was replaced by one which asked respondents to specify their heritage, in terms of Australian, British, European, Asian or other.

The numbers of muscle samples tested from each of the three cattle groups are shown in Table 1. In RSA the original intention was to source just BLD076, CHK078 and STR045 muscles from each group. Although both sides of the Nguni carcasses were purchased for samples there was still not enough product to supply all the samples needed, and the TOP073 was sourced from nine carcasses to make up the shortfall.

Statistical methods

The statistical analysis was undertaken in three stages

A number of analyses were undertaken to characterise the effect of country consumer group and cooking method on the allocation of samples to grades. Also, the boundaries or cut-offs for the different grades were calculated for each country, consumer and cooking method subgroup.

Least squares analyses were used to examine treatment effects (country, cooking method, consumer group within country and supplier) on consumer sensory responses (both a combined meat quality (MQ4) and the individual sensory scores).

The final analyses used the willingness-to-pay (WTP) data collected when the consumers had completed tasting the samples to examine what influenced the consumers’ expectations of what they would need to pay for different grades of beef and whether this assessment was affected by demographic and meat-preference traits.

Weightings and grade cut-offs for the sensory traits

A linear discriminant function was used to calculate the accuracy of using the four sensory scores to allocate samples to the eating-quality grades assigned by the RSA and Australian

Table 1. The number of samples tested in each country for each cattle group supplied (Nguni, Bonsmara and Murray Grey), cooking method, consumer group and muscle (blade BLD096, chuck CHK078, striploin STR045, topside TOP073)

Country	Cattle supplied	Cooking method	Consumer group	Number of muscle samples			
				BLD096	CHK078	STR045	TOP073
RSA	Nguni	Grilled	Rural	5	4	18	9
			Urban	5	4	18	9
	Nguni	Slow cooked	Rural	4	5	18	9
			Urban	4	5	18	9
	Bonsmara	Grilled	Rural	9	9	18	
			Urban	9	9	18	
	Bonsmara	Slow cooked	Rural	9	9	18	
			Urban	9	9	18	
	Murray Grey	Grilled	Rural	8	10	18	
			Urban	8	10	18	
	Murray Grey	Slow cooked	Rural	10	8	18	
			Urban	10	8	18	
Australia	Murray Grey	Grilled	NA	18	18	18	18

NA: segmentation of the Australian consumer group was not applicable consumers (SAS 1997). The accuracy of this allocation was first assessed using the optimal weightings for the different consumer/cooking method subgroups. A composite score was then calculated using the MSA weightings (calculated by weighting tenderness, juiciness, flavour and overall liking scores by 0.3, 0.1, 0.3, 0.3) and the accuracy of the allocation reassessed. Boundaries between the grades using both the optimal weightings within consumer/cooking subgroups and the standard MSA weightings were calculated by assuming that the boundaries occurred where the adjacent discriminant functions were equal (Watson et al. 2008).

Before calculating the mean sensory score for each sample, the 10 sensory scores were ranked and the two highest and two lowest scores clipped to reduce the bias and the variance in the estimate—see Watson et al. (2008). In previous analyses this has been shown to reduce the standard error of individual sample scores by 30% while having little effect on the mean score (Hwang et al. 2008).

Mean sensory scores

The composite meat-quality score (MQ4) was analysed within muscle in a mixed model (SAS 1997) using country, supplier (country), cooking method (country) and consumer (country) as fixed effects, with a random term for sample nested within supplier. As the Australian BLD096 and CHK078 samples were a composite of left and right sides, carcass side could not be tested in these models, although it was possible to do so for the STR045 and TOP073 samples. Also, the imbalance in the experimental design caused by the TOP073 being sourced from only the Nguni carcasses meant that data from all muscles could not be incorporated in a single model. Within-muscle first- and second-order interactions were tested. For all traits the second-order interactions were not significant ($P>0.05$) and so were excluded from the final model. The effects of position within muscle—both main effect and interactions—were tested and found to be non-significant ($P>0.05$) and the results were not included in any of the analyses.

Only the MQ4 analyses are presented in the body of the report, with the analyses for tenderness, flavour, juiciness and overall liking scores presented in Appendixes 2–5.

Willingness to pay

For two reasons, some WTP records were deleted. First, if a respondent did not provide information on all grade levels of WTP this yielded unbalanced data and so the record for the respondent was excluded. Second, if they indicated a lower WTP for higher grade levels their record was excluded. For example, if a consumer indicated a higher WTP for MSA level 2 (‘unsatisfactory’) than for MSA level 3 (‘good everyday’ quality), this suggested that they either did not understand the question or were providing a random answer. Applying these to the RSA data excluded 175 and 7 respondents, respectively, from 720 RSA consumers and 540 in Australia.

The RSA and Australian WTP data were transformed as a ratio of the 3-star estimate. This allowed direct comparison between the RSA and Australian data from this experiment. It also allowed comparison with other datasets collected in Australia, Japan, the United States and Ireland (see Lyford et al. 2010). The WTP ratio was calculated by dividing the WTP estimates for 2-, 4- and 5-star qualities by the 3-star WTP estimate.

A mixed model (SAS 1997) was used for WTP expressed as a ratio of 3-star eating quality. The model included fixed effects for MSA quality grade and cooking method, along with demographic and beef consumption preference variables. The demographic variables included age, sex, occupation, number of adults and children in the household, income, education level and language, and whether or not the respondent was the main purchaser for the household. Beef consumption preference variables included the frequency of eating beef, the level of appreciation for beef in their diet and the preferred degree of doneness for beef. The WTP model also included a random effect for respondent nested within cooking method and consumer group for the RSA data and for respondent only for the Australian model. All first-order interactions between MSA quality grade and other fixed effects were tested and non-significant interactions ($P>0.05$) were excluded from the final model.

Results and discussion

Demographics of the RSA and Australian consumers

Table 2 shows the proportional distribution for demographic traits for RSA and Australian consumers. The RSA consumers were sourced from the three testing sites (rural consumers were sourced from Limpopo and Venda, and urban consumers from Pretoria). The rural consumers were also partitioned into those sourced from Limpopo and those from Venda, but the distributions were very similar and so only the combined results are presented in this report.

The age distribution between rural and urban RSA consumers was similar, with both groups having approximately 70% of the consumers under 30 years of age. The Australian consumers were much older, with more than 50% between 40 and 60 years old.

The rural and urban consumers from RSA, and the Australian consumers, were balanced for sex with approximately 50% in each subclass. Compared with the urban population, the sample of RSA rural consumers comprised fewer professional staff, more students and a higher proportion of unemployed people. The sample of RSA rural consumers comprised about one-third students, while only 13% of the urban consumers were students. In contrast, the Australian sample contained a higher proportion of trade, technical and sales people, and fewer students, than either of the RSA consumer groups.

The distribution of the number of adults in the household was similar between rural and urban samples in RSA, whereas in terms of number of children in the household the rural sample had larger families. Nearly half the urban sample had no children in the household. The Australian sample had a larger number of households with two adults than the RSA sample. The numbers of children in the Australian households were similar to those in RSA.

The rural RSA consumer sample had a higher proportion of panelists in the low-income categories than did the urban sample. For the Australian consumers nearly 70% had income levels between A$4,200 and A$10,400 per month. Not surprisingly as the taste tests were conducted at universities in RSA a large proportion of the consumers had a university education. In comparison, the Australian consumers were sourced largely from suburban Sydney and so had lower numbers of university graduates and a high proportion of consumers among whom high school and trades certificates were the highest levels of education achieved.

For the rural RSA population the Sepedi and Tshivenda languages were the most common, while the urban sample contained a large proportion of consumers for whom Afrikaans was the dominant language, with other respondents scattered amongst the other nine languages listed in Table 2. Australian consumers were largely from English-speaking backgrounds, with only small proportions with British, European or Asian cultural links.

Table 3 characterises the RSA and Australian consumer groups in terms of their meat-eating preferences. For the RSA consumers the rural sample consumed meat less frequently than the urban sample, whereas the RSA urban and the Australian consumers had very similar meat-consumption patterns. For all taste panels the consumers had volunteered to participate so it was not surprising that all groups comprised a large proportion of respondents that considered meat an important part of their diet. For RSA consumers the question on preferred degree of doneness showed that both rural and urban consumers preferred their meat cooked to medium/well-done or well-done levels, while the Australian consumers preferred their meat cooked to between medium/rare and medium/well done.

Characteristics of the sensory scores from RSA and Australian consumers

The standardised weightings for the four sensory traits were estimated within country, consumer group and cooking method. The mean coefficients in Table 4 showed that for RSA consumers the

Table 2. The percentage distribution of demographic traits for RSA (rural and urban) and Australian consumers who participated in taste panels

Trait	Country	Consumer group	Percentage distribution of traits									
Age (years)			<20	20–25	26–30	31–39	40–50	> 50				
	RSA	Rural	12	58	10	9	6	4				
	RSA	Urban	27	45	11	8	5	4				
	Australian	NA	0	11	13	22	54					
Sex			Male	Female								
	RSA	Rural	55	45								
	RSA	Urban	46	54								
	Australian	NA	47	53								
Occupation			Trade	Professional	Administration	Technical	Sales	Labourer	Home	Student	Other	Unemployed
	RSA	Rural	1	16	4	5	3	8	3	32	15	14
	RSA	Urban	2	35	9	9	4	3	0	13	24	1
	Australian	NA	14	22	15	10	14	3	2	1	16	2
No. of adults			1	2	3	4	5	6	7	>8		
	RSA	Rural	7	29	20	19	13	7	4	2		
	RSA	Urban	7	33	22	21	8	4	2	3		
	Australian	NA	10	58	19	9	3	0	0	0		
No. of children			0	1	2	3	4	5	6	7	>8	
	RSA	Rural	11	13	26	24	11	6	4	1	4	
	RSA	Urban	44	17	21	11	4	2	0	1	0	
	Australian	NA	37	16	32	12	2					
Income (rand/month)			<0.8K	0.8–1.4K	1.4–2.5K	2.5– 5K	5–8K	8–11K	11–20K	>20K		
	RSA	Rural	20	19	15	14	10	10	9	3		
	RSA	Urban	4	3	4	7	3	13	26	38		
(A$/month)	Australian	NA	<2.1K	2.1–4.2K	4.2–6.3K	6.3–8.3K	8.3–10.4K	10.4–12.5K	>12.5K			
			2	14	20	29	19	7	9			

Table 2. (cont'd) The proportional distribution of demographic traits for RSA (rural and urban) and Australian consumers who participated in taste panels

Trait	Country	Consumer group	Proportional distribution of traits										
Education level			Primary	High school	Matriculation	Certificate	University						
	RSA	Rural	2	4	28	3	63						
	RSA	Urban	0	1	47	7	45						
	Australian	NA	5	24	41	30	0						
Language			Afrikaans	English	IsiNdebele	IsiXhosa	IsiZulu	Sepedi	Sesotho	Setswana	SiSwati	Tshivenda	Xitsonga
	RSA	Rural	0	0	2	1	0	56	1	2	5	32	16
	RSA	Urban	28	14	3	5	11	14	4	10	4	3	4
Heritage			Australian	British	European	Asian	Other	Didn't say					
	Australian	NA	60	13	13	8	5	1					

Table 3. The proportional distribution of meat-eating preference traits for RSA (rural and urban) and Australian consumers who participated in taste panels

Meat eating habit			Frequency of eating meat (times/week)						
	Country	Consumer	Daily	4–5	2–3	1	0.5	0.25	Never
How often do you eat meat?	RSA	Rural	3	9	31	25	14	16	2
	RSA	Urban	7	21	48	15	5	3	0
	Australian	NA	4	18	55	21	2	0	0
Appreciation of meat			(a)	(b)	(c)	(d)			
	RSA	Rural	39	30	27	4			
	RSA	Urban	41	44	13	1			
	Australian	NA	62	34	4	0			
Degree of doneness			Almost raw	Rare	Med/rare	Medium	Med/well done	Well done	
	RSA	Rural	4	1	3	10	26	56	
	RSA	Urban	1	3	14	14	32	37	
	Australian	NA	0	0	37	32	31	0	

(a) I enjoy red meat. It's an important part of my diet.
(b) I like red meat well enough. It's a regular part of my diet.
(c) I do eat some red meat, although truthfully it wouldn't worry me if I didn't.
(d) I rarely/never eat red meat.

optimal weightings to allocate samples to grades were similar between the urban and rural groups. There was a trend for a lower weighting on juiciness score and a higher weighting on overall-liking score for the slow-cooking method compared with grilling for both the rural and urban consumers in RSA.

The Australian consumers gave the highest weighting for flavour and overall acceptability scores and the lowest weighting for tenderness and juiciness scores. This contrasts to the weighting of 0.3, 0.1, 0.3 and 0.3 for tenderness, juiciness, flavour and overall-liking scores currently used for MSA in Australia (R. Polkinghorne, unpublished data). It is not clear why this sample of Australian consumers yielded divergent data.

Table 5 assesses the impact of using either the optimal or standardised weightings to correctly classify samples into the four grade classes. For the RSA consumers the accuracy of allocating samples to their proper grade was highest for the lowest (2-star) and highest (5-star) quality grades. The Australian consumers showed the same pattern although the drop in accuracy for the 3- and 4-star grades was not as pronounced as found in the RSA consumers. This was a pattern similar to that reported by Watson et al. (2008) for a much larger sample of Australian consumers.

The pattern found for RSA consumers in this study thus suggested that the four sensory traits adequately described eating quality at the highest

Table 4. Standardised weightings for the four sensory traits from the discriminant function to predict eating quality grade for the different countries/consumer/cooking subgroups

Country	Consumer group	Cooking method		Sensory scores		
			Tenderness	Juiciness	Liking of flavour	Overall
RSA	Urban	Grilled	0.18	0.20	0.26	0.36
	Rural	Grilled	0.21	0.23	0.27	0.29
	Urban	Slow cooked	0.21	0.16	0.24	0.39
	Rural	Slow cooked	0.26	0.08	0.25	0.40
Australia	Mixed	Grilled	0.12	0.15	0.25	0.48

Table 5. Percentage accuracy of two discriminant functions to allocate samples to the correct eating-quality grade (as a percentage of the number allocated to the correct grade relative to the number predicted for a particular grade) for RSA and Australian consumers. The first discriminant function was the linear combination of the four sensory scores and the second the composite MQ4 score, which used fixed weightings.

Country	Consumer group	Cooking method	Eating-quality grade				
			2 star	3 star	4 star	5 star	Overall
Linear function of the four sensory scores (T, J, LF, OL)[a]							
RSA	Urban	Grilled	87	55	43	81	63
RSA	Rural	Grilled	80	41	41	74	58
RSA	Urban	Slow cooked	80	59	50	80	65
RSA	Rural	Slow cooked	82	40	31	72	56
Australian	Mixed	Grilled	88	60	53	83	65
Composite MQ4 score using standardised weightings (0.3T + 0.1J + 0.3LF + 0.3OL)[a]							
RSA	Urban	Grilled	82	52	43	76	60
RSA	Rural	Grilled	79	38	37	72	56
RSA	Urban	Slow cooked	77	52	52	80	62
RSA	Rural	Slow cooked	79	38	31	69	54
Australian	Mixed	Grilled	84	59	53	80	64

[a] T: Tenderness; J: Juiciness; LF: Liking of flavour; OL: Overall liking

and lowest grades, but was less effective at describing the intermediate grades. To test whether non-linear factors or interactions between the four sensory traits were contributing to the low accuracy at the intermediate grades, these terms were added to the discriminant function but failed to increase the accuracy of allocation (J.M. Thompson, unpublished data).

The 55–65% accuracies reported in this study (Table 5) were marginally lower than those of Thompson et al. (2008b), Watson et al. (2008) and Polkinghorne et al. (2010) for Korean, Australian and Japanese consumers, respectively. The loss in accuracy resulting from the use of the standardised weightings that are applied in MSA, as opposed to optimal weightings within cooking method and consumer groups, was only of the order of 3%, which would be considered as a marginal loss. Therefore, the use of fixed weightings to calculate a meat-quality score for tenderness, juiciness, flavour and overall liking would result in only a minimal loss in accuracy compared with optimal weightings.

The accuracy of using the discriminant function to allocate samples to grades was marginally lower for the rural consumers than for the urban consumers in RSA. This suggested that eating quality could be slightly better described using sensory scores for urban compared with rural consumers in RSA. Alternatively, this may have been influenced by poorer comprehension of the questionnaire by some rural consumers.

Table 6 showed the boundaries between the grades that were estimated from the RSA consumer data. The estimates within cooking methods provided very similar boundary estimates. The estimates for rural and urban consumers were very similar at the lower grades, but there was a trend for the boundary between the 3- and 4-star grades to be six points lower for rural than for urban consumers.

Generally, the cut-offs reported in Table 6 were similar to those reported by Watson et al. (2008). The cut-offs at the lower quality range (i.e. the boundary between 2 and 3 star) was within a point of MSA cut-offs. The boundary between 3- and 4-star grades was marginally lower than found by Watson et al. (2008), while the boundary at the higher eating quality grades (i.e. between 4- and 5-star) appeared to be similar to that previously reported (Watson et al. 2008; Thompson et al. 2008b). There did appear to be, however, a small consumer effect, in that the rural consumers had a boundary that was six to nine points lower than the urban consumers. In other words, the rural consumers were less discriminating in their view of eating quality at the higher levels of eating quality than were the urban consumers.

In other taste-panel datasets these boundaries have been found to be very consistent both between consumer groups and over time (Thompson 2002). Perhaps the major exception came from the analysis of sensory data from Korean consumers, which found the boundaries to be the reverse of those of South African consumers in that they had a higher boundary between the 2- and 3-star grades but had similar grade boundaries at the 3/4 and 4/5 quality levels (Thompson et al. 2008b). In other words, the Korean consumers were more discriminating than Australian consumers at the lower levels of quality.

Carcass characteristics for animals slaughtered in RSA and Australia

Table 7 showed the mean carcass traits for the three cattle groups. The Nguni bull carcasses from RSA were extremely variable, with a two-fold range in

Table 6. Grade boundaries for RSA and Australian consumers calculated from the discriminant function using the composite MQ4 scores to predict eating-quality grade for the different countries, consumer groups and cooking methods.

Country	Consumer group	Cooking method	MSA grade boundaries		
			2/3	3/4	4/5
	MQ4 [a]				
RSA	Urban	Grilled	42	62	78
RSA	Rural	Grilled	43	60	72
RSA	Urban	Slow cooked	41	61	79
RSA	Rural	Slow cooked	42	58	70
Australian	Mixed	Grilled	39	62	78

[a] MQ4 weightings were 0.3, 0.1, 0.3, 0.3 for tenderness, juiciness, liking of flavour and overall liking, respectively

carcass weight. These carcasses were all extremely lean and, given the range in ages, had almost a fourfold range in ossification score. As expected these carcasses also had very low marbling scores. Temperature at pH6 could not be estimated on three carcasses because pH did not even approach 6, possibly reflecting low glycogen levels at slaughter. However, excluding these carcasses the mean temperature at pH6 was of the order of 20˚C, indicating good compliance with the MSA pH/temperature window. The ultimate pH for this group of carcasses was generally high, with only one carcass having an ultimate pH lower than 5.7. Consistent with their high ultimate pH, the Nguni carcasses had very high meat-colour scores with a mean of about 5.

The Bonsmara steer carcasses from RSA, with a mean carcass weight of 250 kg (Table 7), were much heavier than the Nguni bull carcasses They were also fatter than the Ngunis, with lower mean ossification and higher marbling scores. The Bonsmara steer carcasses had an extremely rapid pH decline, with a mean temperature at pH6 of 41˚C. This would have been due to excessive stimulation in the early post-mortem period. They did have a low ultimate pH, with all carcasses lower than 5.7. In keeping with the low ultimate pH the Bonsmara carcasses had low meat-colour scores.

The Murray Grey cattle from Australia were the heaviest group, with a mean weight of 319 kg (Table 7). They were a similar fatness to the Bonsmara carcasses and had similar eye-muscle area, ossification and marbling scores. Although they were pasture fed, all had low ultimate pH readings (all below 5.7). The Murray Grey carcasses had similar meat-colour scores to the Bonsmara carcasses, indicating adequate glycogen reserves in both these groups before slaughter. The temperatures at pH6 for the Murray Grey carcasses at a mean of 31˚C were intermediate between the Bonsmara and Nguni carcasses. There was, however, some variation within the group so the extremes did overlap with the Nguni and Bonsmara carcasses.

Table 7. Mean carcass traits for the three groups of carcasses used to produce the grilled and slow-cooked samples

Cattle breed / traits	Mean	SD	Min/Max
Nguni (*n*=18)			
Hot carcass weight	161	48	109/293
Ribfat	0.83	0.70	0/2.0
Eye muscle area (EMA)	49.6	12.7	35/74
Ossification (Uoss)	180	81.3	130/500
Marbling (Umb)	219	56	140/370
Meat colour	4.78	0.94	3.0/6.0
temp@pH6	19.7	4.4	11.6/28.6
Ultimate pH (pHu)	5.99	0.31	5.59/6.61
Bonsmara (*n*=18)			
Hot carcass weight	250	15	222/296
Ribfat	9	3	5/16
EMA	65.6	6.5	55/79
Uoss	137	10	120/160
UMb	308	51	190/420
Meat colour	1.61	0.42	1.33/3.00
temp@pH6	41.3	3.5	35.0/48.2
pHu	5.56	0.05	5.49/5.66
Murray Grey (*n*=18)			
Hot carcass weight	319	11	291/337
Ribfat	10	3	6/14
EMA	68	5	60/75
Uoss	141	7	130/160
UMb	302	53	190/410
Meat colour	1.71	0.36	1.33/3.00
temp@pH6	30.8	4.3	24.6/42.0
pHu	5.61	0.04	5.52/5.68

Sensory scores for samples tested in RSA and Australia

Raw sensory scores for grilled and slow-cooked samples tested in RSA and grilled samples tested in Australia are shown in Table 8. While there was no difference between the demographics for consumers sampled at Venda and Limpopo, the mean sample sensory scores showed that scores given by consumers at Limpopo tended to be higher for grilling than for the slow-cooking method (Table 8). Within each of the sites and cooking methods there was a trend for variances to be higher for juiciness scores than for other sensory traits. Mean sensory scores for both cooking methods for RSA consumers from Pretoria and Limpopo were similar. Correlations between the different sensory traits were calculated for the three consumer groups in RSA and the Australian group of consumers (Table 9). In all cases structure of the correlation matrices was similar, with the highest correlations between MQ4 and tenderness, flavour and overall liking scores. With the exception of the Australian data the lowest correlations were between juiciness scores and tenderness and flavour scores.

Given that the carcass traits (e.g. carcass weight and ultimate pH) and the processing conditions (temperature at pH6) varied greatly for the three different groups of carcasses it was prudent to check if this influenced the relationships between the different sensory scores. Table 10 shows the correlations between the four sensory traits for the different groups of cattle. These correlation matrices were notable in that they were very similar for the different cattle groups, despite the extremes in processing conditions. The highest correlations were between

Table 8. Raw means sensory standard deviation and range for the three different testing sites for grilling and slow-cooking methods for RSA consumers and for grilling for Australian consumers

Country/consumer group/tasting site/sensory score	Grilling			Slow cooking		
	Mean	SD	Min/Max	Mean	SD	Min/Max
RSA,/rural Limpopo						
Number of samples	72			36		
Tenderness	60.3	12.4	20/80	54.3	12.8	29/79
Juiciness	62.0	15.8	14/89	56.6	16.0	21/89
Flavour	59.9	14.5	14/87	54.0	13.3	32/79
Overall liking	61.9	12.2	23/89	49.5	13.7	20/75
MQ4	61.9	14.5	12/86	56.2	14.1	29/84
RSA/rural Venda						
Number of samples	36			72		
Tenderness	52.4	12.5	27/76	52.0	11.7	25/81
Juiciness	54.5	14.4	24/81	55.4	16.3	17/84
Flavour	51.2	15.9	21/80	52.5	13.0	22/81
Overall liking	54.8	11.1	33/78	44.3	11.7	21/69
MQ4	53.0	16.5	21/84	52.8	14.1	20/84
RSA/urban Pretoria						
Number of samples	108			108		
Tenderness	58.7	12.3	29/79	57.8	13.2	30/88
Juiciness	61.6	16.8	11/90	62.0	17.4	20/92
Flavour	56.2	12.1	29/82	57.2	12.7	31/85
Overall liking	62.7	12.0	33/91	54.4	15.6	24/90
MQ4	58.1	12.8	27/82	57.0	13.3	31/89
Australia						
Number of samples	72					
Tenderness	45.9	17.2	7/90			
Juiciness	52.4	16.3	15/82			
Flavour	54.3	12.5	17/76			
Overall liking	51.3	14.1	17/76			
MQ4	50.2	14.0	14/79			

the MQ4 scores and tenderness, flavour and overall liking. The lowest correlations were between juiciness scores and tenderness and flavour scores.

Treatment effects on MQ4 scores

The F ratios for the treatment effects on MQ4 scores for the different muscles are shown in Tables 11 and 12. For the BLD096, only supplier (country) was significant (*P*<0.05, Table 11), while for the CHK078 the cooking method × consumer (country) and supplier × consumer (country) interactions were significant, along with main effects for country, supplier (country) and consumer (country) (*P*<0.05, Table 11). For the STR045, supplier × cooking method (country), supplier × consumer (country) and side × supplier (country) interactions were significant, along with main effects for supplier, cooking method and consumer all nested within country (*P*<0.05, Table 12).

The original design did not include the TOP073 being tested in Australia, or being sent to RSA. However, the small Nguni carcasses did not allow sufficient BLD096 and CHK078 samples to be produced from these muscles and so the TOP073 was included in the Nguni samples prepared and tasted in RSA. Fortunately, the TOP073 had been collected in Australia for use in other experiments so it could be included in the Australian taste panels. For the TOP073 samples, only the country term was significant (Table 12, *P*<0.05).

Appendix 2 presents the analyses for tenderness score using the same table format as for MQ4 score (Tables A2.1 and A2.2). Similarly, Appendix 3 presents the results for flavour score, Appendix 4 the results for juiciness score and Appendix 5 the results for overall satisfaction scores. Because of the high correlations between the sensory scores these analyses generally showed a similar pattern to the MQ4 score. The significance of the interactions varied slightly in magnitude between the different sensory scores, although the direction and magnitude of the effects were similar. Therefore the major discussion will focus on the MQ4 results other than when the different sensory scores deviated markedly from these.

Table 9. Correlation coefficients for the four consumer sensory traits for the samples fed to RSA consumers at Limpopo, Pretoria and Venda, and Australian consumers

	Tenderness	Flavour	Juiciness	Overall liking	MQ4
Limpopo (*n*=108)					
Tenderness	1.00	0.81	0.59	0.78	0.91
Flavour		1.00	0.65	0.92	0.95
Juiciness			1.00	0.61	0.70
Overall liking				1.00	0.94
MQ4					1.00
Pretoria (*n*=216)					
Tenderness	1.00	0.72	0.65	0.82	0.91
Flavour		1.00	0.62	0.90	0.91
Juiciness			1.00	0.72	0.75
Overall liking				1.00	0.96
MQ4					1.00
Venda (*n*=108)					
Tenderness	1.00	0.70	0.50	0.70	0.87
Flavour		1.00	0.38	0.93	0.93
Juiciness			1.00	0.37	0.51
Overall liking				1.00	0.93
MQ4					1.00
Australia (*n*=72					
Tenderness	1.00	0.80	0.85	0.92	0.95
Flavour		1.00	0.90	0.91	0.91
Juiciness			1.00	0.95	0.95
Overall liking				1.00	0.99
MQ4					1.00

Table 10. Correlation coefficients for the four consumer sensory traits for the samples from the three cattle groups tested by RSA consumers

	Tenderness	Flavour	Juiciness	Overall liking	MQ4
Nguni (*n*=108)					
Tenderness	1.00	0.67	0.64	0.75	0.90
Flavour		1.00	0.48	0.90	0.89
Juiciness			1.00	0.57	0.68
Overall liking				1.00	0.93
MQ4					1.00
Bonsmara (*n*=216)					
Tenderness	1.00	0.77	0.70	0.80	0.93
Flavour		1.00	0.67	0.88	0.92
Juiciness			1.00	0.70	0.79
Overall liking				1.00	0.93
MQ4					1.00
MG (*n*=108)					
Tenderness	1.00	0.63	0.40	0.62	0.82
Flavour		1.00	0.53	0.91	0.92
Juiciness			1.00	0.52	0.60
Overall liking				1.00	0.92
MQ4					1.00

Table 11. Analysis of variance (F ratios) for the effect of country, cooking method, supplier, consumer and carcass side on MQ4 score for the blade (BLD096) and chuck (CHK078) samples

Independent variables	NDF, DDF[a]	BLD096	CHK078
Country	1, 56	0.77	**10.75**
Supplier (country)	2, 56	**28.40**	**10.92**
Cooking method (country)	1, 56	3.47	0.26
Consumer (country)	1, 41	0.01	**20.52**
Supplier × cook (country)	2, 56	1.59	0.78
Cooking method × consumer (country)	1, 41	0.89	**4.28**
Supplier × consumer (country)	2, 41	2.42	**4.01**

[a] NDF = numerator degrees of freedom; DDF = denominator degrees of freedom
Bold numbers are statistically significantly different at P<0.05.

Table 12. Analysis of variance (F ratios) for the effect of country, cook, supplier, consumer and carcass side on MQ4 score for the striploin (STR045) and topside (TOP073) samples

Independent variables	NDF, DDF[a]	STR045	NDF,DDF	TOP073
Country	1, 118	0.03	1,32	**12.71**
Supplier (country)	2, 118	**24.80**		
Cooking method (country)	1, 118	**21.34**	1,32	0.42
Consumer (country)	2, 101	**5.99**	1,15	0.32
Side	1, 101	0.86	1,15	0.84
Supplier × cooking method (country)	2, 118	**3.42**	1,15	1.85
Cooking method × consumer (country)	1, 101	0.42		
Supplier × consumer (country)	2, 101	**5.48**		
Side × supplier (country)	3, 101	**4.71**	1,15	0.33

[a] NDF = numerator degrees of freedom; DDF = denominator degrees of freedom
Bold F ratios are statistically significantly different at P<0.05.

For the BLD096 the supplier (country) effect showed that the Nguni samples had an MQ4 score of 43 compared with about 60 for BLD096 samples from the Bonsmara and Murray Grey carcasses. This may reflect the high ultimate pH readings in the Nguni carcasses, which would have increased toughness (i.e. maximum toughness occurs at an ultimate pH of 6), although it was of note that the same contrast (Nguni versus Bonsmara and Murray Grey) was not evident in STR045 and CHK078 samples. The supplier (country) effect was most significant for tenderness, overall liking and flavour scores (P<0.001), and only just attained significance for juiciness score (see Appendixes 2–5).

For the CHK078 the cooking method × consumer (country) interaction showed that urban consumers gave a higher MQ4 score than rural consumers, the effect being greater when slow cooked compared with grilling (the difference between urban and rural consumers was about 5 MQ4 units higher for grilling and 12 MQ4 units for slow cooking: Table 13). A similar trend was evident for the supplier × consumer (country) interaction where the urban consumers gave scores that were 12 units higher than rural consumers for CHK078 samples from the Nguni and Bonsmara, but there was no difference between scores given by the urban and rural consumers for the Murray Grey CHK078 samples (Table 14).

The STR045 had the largest number of samples tested. There were three interactions that were significant (P<0.05): cooking method × supplier (country), supplier × consumer (country) and, interestingly, carcass side × supplier (country). Predicted means for the supplier × consumer (country) inter-

Table 13. Predicted means for MQ4 score for the interaction between cooking method and consumer (country) for the blade (BLD096), chuck (CHK078), striploin (STR045) and topside (TOP073) samples

Muscle	Cooking method		
	Consumer	Grilling	Slow cooking
BLD096	Rural (RSA)	54.5 (2.1)	56.7 (2.1)
	Urban (RSA)	52.5 (2.1)	58.4 (2.1)
	Australia	57.7 (2.2)	
CHK078	Rural (RSA)	**58.3 (2.0)**	**55.8 (2.0)**
	Urban (RSA)	**62.9 (2.0)**	**67.7 (2.0)**
	Australia	**53.2 (2.2)**	
STR045	Rural (RSA)	58.7 (1.4)	50.9 (1.4)
	Urban (RSA)	60.8 (1.4)	54.6 (1.4)
	Australia	56.7 (2.4)	
TOP073	Rural (RSA)	46.8 (3.1)	40.6 (3.1)
	Urban (RSA)	40.8 (3.1)	43.0 (3.1)
	Australia	33.2 (2.2)	

Bold type means within consumer group and muscle were significantly different for the different cooking methods (P<0.05).

Table 14. Predicted means for MQ4 score for the interaction between supplier and cooking method (country) for the blade (BLD096), chuck (CHK078) and striploin (STR045) muscles

Muscle	Cooking method	Supplier		
	(country)	Nguni	Bonsmara	Murray Grey
BLD096	Grilling (RSA)	**37.7 (3.0)**	60.4 (2.2)	62.4(2.4)
	Slow cooking (RSA)	**47.8 (3.4)**	61.8 (2.3)	63.0 (2.2)
	Grilling (Australia)			57.7 (2.2)
CHK078	Grilling (RSA)	53.3 (3.5)	68.7 (2.4)	59.8 (2.2)
	Slow cooking (RSA)	58.8 (3.2)	67.4 (2.4)	58.9 (2.5)
	Grilling (Australia)			53.2 (2.2)
STR045	Grilling (RSA)	52.1 (1.9)	**58.6 (1.9)**	**68.6 (1.9)**
	Slow cooking (RSA)	50.7 (1.9)	**48.5 (1.9)**	**58.9 (1.9)**
	Grill (Australia)			56.7 (2.4)

Bold type means within supplier and muscle were significantly different for the different cooking methods (P<0.05) action are shown in Table 13 for the STR045 sample. For this low connective tissue cut there were relatively small differences between consumers in the MQ4 scores for samples from the Bonsmara and Murray Grey carcasses, although for the Nguni carcasses rural consumers scored this cut lower than urban consumers by almost 7 MQ4 units.

Predicted MQ4 scores for the supplier × cooking method (country) interaction are shown in Table 15 for the STR045 muscle. For the STR045 samples from the Bonsmara and Murray Grey carcasses the differences were as expected: MQ4 scores for low connective tissue cuts from reasonably young carcasses were higher when grilled than when slow cooked. It is interesting to speculate whether the lack of a difference in the STR045 samples from the Nguni carcasses was a reflection of the higher connective tissue content, or the high ultimate pH in these carcasses. For the BLD096 samples this difference between cooking methods was reversed in the Nguni carcasses.

The side × supplier (country) interaction was significant for the STR045 samples ($P<0.05$, Table 12). The predicted means for this interaction are shown in Table 16. They indicate that the significance of this interaction was due solely to a side effect for the STR045 samples in the Nguni carcasses. For the Bonsmara samples tested by RSA consumers, and the Murray Grey samples tested by both RSA and Australian consumers, the side × supplier (country) interaction was not significant ($P>0.05$, Table 12).

It is interesting to hypothesise on the cause of this interaction. To achieve so high an ultimate pH reading (a mean pHu of 6.0) the Nguni carcasses were assumed to have low glycogen at slaughter. Immediately after knocking all RSA carcasses were suspended by the left leg, then changed to a double shackle within 15 minutes after slaughter. This 15-minute window while the carcass was suspended by the left leg and the right leg hung down in the tenderstretch position, thereby placing tension on most of

Table 15. Predicted means for MQ4 score for the interaction between supplier and consumer (country) effects for the blade (BLD096), chuck (CHK078) and striploin (STR045) muscles

Muscle	Consumer	Supplier		
		Nguni	Bonsmara	Murray Grey
BLD096	Rural (RSA)	**45.7 (3.2)**	58.3 (2.2)	62.8 (2.2)
	Urban (RSA)	**39.8 (3.2)**	63.9 (2.2)	62.5 (2.2)
	Australia			57.7 (2.2)
CHK078	Rural (RSA)	**49.8 (3.1)**	**62.6 (2.2)**	58.6 (2.2)
	Urban (RSA)	**62.3 (3.1)**	**73.5 (2.2)**	60.1 (2.2)
	Australia			53.2 (2.2)
STR045	Rural (RSA)	**48.1 (1.9)**	**51.2 (1.9)**	**65.1 (1.9)**
	Urban (RSA)	**54.7 (1.9)**	**56.0 (1.9)**	**62.4 (1.9)**
	Australia			**56.7 (2.4)**

Bold type means within supplier and muscle were significantly different for the different consumer groups ($P<0.05$)

Table 16. Predicted means for MQ4 score for the interaction between carcass side by supplier (country) for the blade (BLD096), chuck (CHK078) and striploin (STR045) muscles

Muscle	Consumer		Supplier		
		Nguni	Bonsmara	Murray Grey (RSA)	Murray Grey (Australia)
STR045	Left	**48.4 (1.9)**	54.9 (1.9)	65.5	53.9 (3.6)
	Right	**54.5 (1.9)**	52.2 (1.9)	62.0	59.5 (3.2)
TOP073	Left	44.7 (2.4)			33.6 (3.3)
	Right	40.8 (2.4)			32.7 (2.9)

Bold type means within supplier and muscle were significantly different for the different side ($P<0.05$)

the muscles in the leg and striploin (Hwang et al. 2002) is presumably where the leg effect occurred. Attainment of rigor is defined as when the muscles in the carcasses run out of ATP (Thompson et al. 2006). In the Nguni carcasses with low glycogen levels the significance of the leg interaction suggests that these carcasses started to enter rigor while still suspended by the left leg on the slaughter chain. This would suggest that the stretching effect occurred almost immediately after slaughter. This would be an interesting area to follow up on as the full onset of rigor would have occurred much later but, with reduced glycogen reserves, a stretching effect was nevertheless evident to consumers.

The side interaction demonstrates the power of the consumer testing protocol to quantify treatment effects on palatability. It would be interesting to measure sarcomere length in the striploin muscle to confirm that some shortening did occur in the striploin from the left side compared with that from the right side.

It is also interesting to speculate on the possibility that the Bonsmara carcasses, which were exposed to extremely high rates of pH decline and high temperatures at rigor, also went into rigor at an early stage. While there was no evidence of a side interaction in the Bonsmara carcasses the extreme pH and temperature conditions might be expected to maximise proteolysis in the short term while inhibiting later ageing due to enzyme autolysis (Thomson et al. 2008).

Although there were comparisons between Australian and RSA consumers these were generally unbalanced for either cooking method (Table 13), supplier (Table 14) or consumer (Table 15). To provide a balanced comparison, the data on grilled cooking from Australian carcasses were analysed separately (J.M. Thompson, unpublished data). This analysis showed that for grilled samples from the Murray Grey carcasses (BLD096, CHK078 and STR045) the RSA consumers gave scores that were 2 to 12 MQ4 units higher than those from Australian consumers for the same samples. In other words, the RSA consumers were less discriminating for beef quality.

RSA and Australian consumers' willingness to pay for eating quality

At the conclusion of the taste-panel session consumers were asked to nominate what they would be willing to pay for meat they had labeled as 2-star (or 'unsatisfactory'), 3-star (or 'good everyday'), 4-star (or 'better than everyday') or 5-star (or 'premium') eating quality. This part of the questionnaire was completed after the consumers had tasted and scored the samples, and so had no effect on the consumers scoring of the meat samples.

The raw means, variance and range for WTP estimates from both RSA and Australian consumers are shown in Table 17 in both the currency of the country and also as a ratio of 3-star WTP. For RSA consumers the average price consumers nominated for 3-star product was 32 Rand/kg, with approximately half that offered for 2-star or 'unsatisfactory' quality and nearly 2.5 times the 'good everyday' price for the 5-star or 'premium' quality grade. Similar relative differences between the WTP for the different grades were evident for Australian consumers: 2-star product was valued at less than half the value of 3-star, and 5-star product at over twice the value of 3 star. For both RSA and Australian consumers the estimates nominated by consumers for the higher quality grades were more variable, with a twofold increase in variance for the 5-star or 'premium' quality grade relative to the 3-star or 'good everyday' quality.

The significance of main effects and interactions on WTP expressed as a ratio of 3-star product, for both RSA and Australian consumers are shown in Table 18. As noted earlier, the RSA data were trimmed so respondents who did not provide a WTP estimate for every grade were excluded from the data. This effectively excluded 24% of the RSA data which, under any data validation regime, was a very high exclusion rate. However, the main interest in this study was in testing whether main effects and interactions between demographic traits and quality grade had a significant effect on WTP estimates, and restricting the data to those respondents that gave answers to all grades allowed such estimation. To test whether this had biased the modelling, the analyses were re-run and the same final models were obtained using both the full and reduced datasets.

Table 18 shows that quality grade had the largest effect on WTP for both RSA and Australian consumers when expressed as a ratio of the 3-star quality (P<0.001 for both RSA and Australian consumers). This was clear evidence that consumers were willing to pay more for higher quality beef. While this may appear to be self-evident the meat industry is often reluctant to acknowledge this fact, saying that the consumer only buys on price and will not pay more for higher quality.

All first-order interactions between quality grade and demographic and meat consumption habits were tested. Two interactions were significant (P<0.05) for RSA consumers, while three were significant (P<0.05) for Australian consumers. The important findings from these analyses were, first, the clear relationship between quality and WTP and, second,

Table 17. Raw means, variance and range for willingness to pay (WTP) for RSA and Australian consumers for the four grade categories expressed in the country's currency (Rand/kg and A$/kg) and as a ratio of 3-star or 'good everyday' quality (WTP ratio)

Grade category	WTP			WTP ratio of 3 star		
	Mean	S.D.	Range	Mean	S.D.	Range
RSA	Rand/kg					
2 star	15.4	12.7	0–130	0.47	0.24	0–1.00
3 star	32.1	16.1	3–130	1.00		
4 star	47.6	23.3	7–150	1.55	0.48	1–5.33
5 star	70.6	34.9	10–240	2.35	1.09	1–13.5
Australian	A$/kg					
2 star	6.46	4.08	0–24	0.44	0.20	0–1.0
3 star	14.30	5.29	3–33	1.00		
4 star	21.09	7.58	5–51	1.51	0.29	1.0–3.25
5 star	29.46	10.61	5–80	2.15	0.62	1.15–5.50

Table 18. Analysis of variance for willingness to pay expressed as a ratio of the 'good everyday' quality for RSA and Australian consumers

Independent variable	RSA		Australian	
	NDF, DDF	F ratio	NDF, DDF	F ratio
Quality grade	3, 1518	**146.55*** **	3, 1551	**602.59*** **
Consumer group	1, 465	0.92		
Cooking method	1, 465	0.47		
Age category	5, 1518	**2.24***	3, 1551	**8.33*** **
Gender	1, 1559	0.00	1, 1551	**4.83*** **
Occupation	9, 1559	0.51	9, 1551	0.99
Number of adults	8, 1559	1.91	6, 1551	0.59
Number of children	8, 1559	0.65	5, 1551	0.99
Income category	7, 1559	1.09	6, 1551	**3.20** **
Education level	4, 1559	0.24	3, 1531	**3.42** **
Language	11, 1559	1.02	1, 1551	
Heritage			1, 1551	0.66
Main purchaser	1, 1559	0.87	4, 1551	1.14
Often eat	6, 1559	0.53	2, 1551	**3.40** **
Statement of appreciation	3, 1559	0.47	2, 1551	0.19
Degree of doneness	5, 1559	0.82	2, 1551	0.97
MSA grade × age	15, 1559	**2.78*** **	9, 1551	**10.74*** **
MSA grade × adults	24, 1559	**2.20*** **		
MSA grade × education			9, 1551	2.30*
MSA grade × often eat			12, 1551	**3.19*** **

Significant F ratios are in bold type.
*, **, *** indicate significance at P<0.05, 0.01 and 0.001, respectively.

that apart from several specific interactions, the demographics or meat-eating preferences of consumers had little impact on the consumers WTP for different quality grades of beef. This result should give the retail sector confidence that consumers will pay for meat quality, and the premium associated with higher quality could be used to offset some of the additional costs in production, processing and value-adding that are needed to achieve this increase in quality.

WTP for MSA beef-quality grades was examined in nearly 7,000 consumers by Lyford et al. (2010). This set of consumer data was collected as part of a large number of consumer sensory tests conducted in Australia, Japan, the United States and Ireland. Like us, Lyford et al. (2010) found that few demographic factors influenced a consumer's WTP for beef prepared by a variety of cooking methods. From the current study and that of Lyford et al. (2010) it can be concluded that consumers are willing to pay more for beef of higher quality and that the increments between grades are substantial.

The quality grade × age interaction on WTP expressed as a ratio of 3-star or 'good everyday' quality was highly significant for both RSA and Australian consumers (*P*<0.001, Table 18). Both analyses showed that younger consumers were willing to pay more for quality at the higher grades. From the ratios presented in Table 19 the younger consumers showed an increase of about 50% in their WTP for higher quality compared to older consumers.

The same interaction was also found by Lyford et al. (2010). The consistency of this interaction in different countries would suggest that, despite large differences in cultural background and income, this behaviour is innate in consumers; that is, younger consumers value quality more than older consumers, even although in many instances younger consumers have less money to purchase quality goods and services.

Given that the RSA study was undertaken to specifically characterise any differences between urban and rural consumers the second-order interaction for consumer × quality grade × age category was tested to investigate whether the quality grade × age category interaction was the same between rural and urban consumers (J.M. Thompson, unpublished data). This interaction did not approach significance, confirming that the same quality grade × age category interaction was evident in both the rural and urban consumer groups.

For RSA consumers the number of adults in the household interacted with WTP estimates expressed as a ratio of 3-star quality (Table 18). From the predicted means in Table 20 it was evident that part of this interaction was due to the very low WTP of consumers who lived in households with no adults. However, this interaction must be treated with caution as there were only eight households with no adults.

There was also a trend for those RSA households with more than eight adults to have a higher WTP than other households (Table 20). When this inter-

Table 19. Predicted means for willingness to pay expressed as a ratio of the 'good everyday' quality estimate for the MSA quality grade × age interaction

Trait	Age category (years)	2 star	3 star	4 star	5 star	Mean standard error
RSA						
Age 1	<20	0.44	0.98	1.47	2.33	0.11
Age 2	20–25	0.46	1.01	1.58	2.43	0.10
Age 3	26–30	0.45	1.02	1.43	2.04	0.12
Age 4	31–39	0.40	0.97	1.33	2.04	0.14
Age 5	40–50	0.65	1.00	1.32	1.93	0.14
Age 6	>50	0.50	0.97	1.33	1.93	0.16
Australian						
Age 1	<20	–	–	–	–	–
Age 2	20–25	0.35	1.00	1.68	2.61	0.07
Age 3	26–30	0.43	0.99	1.45	2.07	0.07
Age 4	31–39	0.43	0.98	1.49	2.08	0.07
Age 5	40–60	0.43	0.98	1.48	2.08	0.06

action was investigated further the interaction between consumer group × quality grade × number of adults was significant (*P*<0.05) and was driven by those rural households with eight or more adults having a WTP that had a fourfold increase for 'premium' quality, compared with a twofold increase for urban consumers with more than eight adults per household. This may reflect the high disposable income available for food purchases when young people are sharing a household. However, it is difficult to understand why this would be different for rural and urban consumers, and again the result should be treated with caution.

For Australian consumers the interactions between MSA grade × education and MSA grade × frequency of eating meat were significant (*P*<0.05). The predicted means for these interactions are shown in Tables 21 and 22.

There was a trend for those consumers with lower education levels (Table 21) to have a lower WTP for quality, particularly at the 4- and 5-star levels. Lyford et al. (2010) had no data on education level on which to test this interaction.

While there was a trend towards lower WTP at the lower levels of quality for consumers who ate meat frequently (i.e. daily or several times a week) this was reversed at the higher qualities (Table 22). In other words, those consumers who ate meat frequently valued eating quality more than those who ate meat less frequently.

Table 20. Predicted means for RSA consumers for willingness to pay expressed as a ratio of 'good everyday' quality for the quality grade × number of adults in the household interaction

Traits	2 star	3 star	4 star	5 star	Mean standard error
Adults 0	0.28	1.16	1.54	1.69	0.44
Adults 1	0.54	0.99	1.48	2.19	0.13
Adults 2	0.49	0.97	1.39	1.99	0.09
Adults 3	0.46	0.99	1.52	2.37	0.12
Adults 4	0.51	0.96	1.35	1.90	0.10
Adults 5	0.48	0.96	1.35	2.10	0.12
Adults 6	0.43	0.96	1.37	2.16	0.15
Adults 7	0.62	0.96	1.27	1.90	0.18
Adults 8	0.52	0.97	1.43	2.76	0.18

Table 21. Predicted means for Australian consumers for willingness to pay expressed as a ratio of 'good everyday' quality for the quality grade × education level achieved interaction

Traits	2 star	3 star	4 star	5 star	Mean standard error
Primary school	0.34	0.97	1.46	2.11	0.09
High school	0.43	0.99	1.51	2.13	0.06
Matriculation	0.43	1.00	1.56	2.28	0.06
Certificate	0.44	0.99	1.57	2.34	0.06
University					

Table 22. Predicted means for Australian consumers for willingness to pay expressed as a ratio of 'good everyday' quality for the quality grade × frequency of eating meat interaction

Traits	2 star	3 star	4 star	5 star	Mean standard error
Daily	0.40	1.00	1.66	2.45	0.10
4–5 times a week	0.37	0.97	1.49	2.19	0.06
2–3 times a week	0.39	0.99	1.52	2.21	0.06
Once a week	0.42	0.99	1.45	2.00	0.06
Once every 2 weeks	0.47	0.99	1.51	2.23	0.11

General discussion

Consumer data indicated that RSA consumers had scored meat samples in a very similar manner to Australian consumers. They placed a similar weighting on flavour and the lowest weighting on juiciness, which generally aligned with Australian consumers' rankings.

The formation of a composite meat-quality score using fixed weightings, as opposed to optimal weightings for each dataset, resulted in only a minor loss in accuracy compared to using a composite score to allocate samples to the correct grade. Certainly, there were no differences between RSA consumers from rural and urban backgrounds. It was interesting that, for RSA consumers, the accuracy of using the discriminant function to allocate samples based on a linear function of their sensory scores was better at the higher and lower quality grades. This effect was more pronounced in the RSA than the Australian consumers. In other words, quality at the extremes was clearly a function of sensory scores, but less clearly so at the intermediate levels of quality.

The only notable difference between rural and urban consumers in RSA was that rural consumers had a lower boundary between the 4- and 5-star grades than did the urban consumers. This suggested that the rural consumers in RSA had lower expectations as to what resembled 5-star eating quality. It was interesting that, compared to Australian consumers, the RSA urban consumers had similar boundaries for 2- and 5-star product but slightly lower boundaries for 3- and 4-star product. In other words, the RSA urban and Australian consumers had a similar expectation of beef eating quality.

The overall conclusion from this study was that there were only subtle differences between rural and urban consumers in RSA, and between RSA and Australian consumers. Although the boundaries between grades varied slightly between consumer groups, all consumer groups showed substantial increases in boundaries between grades. The accuracy of using a fixed weighting to combine sensory scores into composite scores to allocate samples to the different grades was high enough in all consumer groups to support a quality description based on sensory scores.

The processing of the three groups of cattle used in this experiment varied enormously. The Australian carcasses went through rigor at about 30˚C which, by Australian standards, was slightly on the high side, but much lower than the Bonsmara carcasses, which went through rigor at 41˚C. This was an extremely high temperature at rigor and these carcasses would undoubtedly have heat shortened (Thompson 2002). It is likely that meat from the Bonsmara carcasses would have achieved maximum eating quality at 4 days ageing and would be unlikely to improve with further ageing (Thomson et al. 2008). Although not measured in our study the meat would have exhibited a high drip loss. Nevertheless, this was not supported by lower juiciness scores in samples from Bonsmara compared with the Nguni or Murray Grey carcasses. The temperature at rigor for the Nguni carcasses should be treated with caution, however, as from the ultimate pH readings a number of the carcasses did not have enough glycogen in the muscle to achieve pH6.0.

The extremes in processing of the RSA carcasses would have affected sensory scores, although these effects were totally confounded with supplier. The correlations between sensory scores showed a small difference between RSA and Australian consumers. The RSA consumers had lower correlations between juiciness, flavour and overall liking than Australian consumers. This could have been in part a function of the extremes in processing the RSA samples. The normal high correlations between the different sensory scores would have been disrupted by extremes in juiciness and by flavour differences arising from the high ultimate pH in the Nguni carcasses and the high rigor temperature in the Bonsmara carcasses. The fact that the same low correlations existed within the Australian samples tasted by RSA consumers could simply reflect a halo effect (Durier et al. 1997; Kunert 1998).

There were differences between the suppliers with often the Nguni carcasses having the lowest quality and the Bonsmara and Murray Grey samples being similar or showing only small differences depending upon the muscle in question. The extremes in ultimate pH for the Nguni carcasses most likely led to a side interaction for the striploin muscle.

With the exception of the BLD096 samples, the eating quality of the Nguni was surprisingly good, even given the extremes in processing. The Bonsmara product was eaten after 4-days ageing but, because of the rapid rate of glycolysis, it is unlikely it would have improved further with ageing.

It is interesting that the direct comparison between RSA and Australian consumers showed that RSA consumers scored the same samples 2–12 MQ4 points higher than the Australian consumers.

The WTP data gave a clear indication that both RSA and Australian consumers were prepared to pay for higher quality beef. By and large, the increases in price with eating quality were not influenced by demographic factors, in particular whether it was being purchased by rural or urban consumers. In both the RSA and Australian data there was an interaction between age and quality grade, whereby younger consumers indicated they would pay more for higher quality meat. Given that a similar interaction has been reported for other consumer groups in Australia, Japan, the United States and Ireland, it is likely that this interaction simply reflects consumer behaviour that is constant across geographic and cultural boundaries.

Implications for future work

This study aimed to understand the factors that influence the sensory perception of meat quality amongst urban and rural consumers in RSA. There is now an opportunity to use these results to underpin new supply-chain research aimed at developing among RSA consumers a niche market for product from cattle from smallholder farms. The results from this project showed that RSA rural and urban consumers were in broad agreement as to what compromised eating quality. Additional research may be required through South Africa's meat grading and marketing policy areas to support the suggested further research.

The effect of the processing variations identified in the current study would need to be confirmed in a subsequent study. However, the indications are that the cuts from older pasture-finished bulls from the indigenous breeds could produce an acceptable product for both rural and urban consumers, providing that the animals had adequate glycogen reserves before slaughter and that an appropriate amount of post-slaughter stimulation was applied.

The current pasture-based production system could be used by smallholder beef farmers to provide product for a new supply chain. Results of this project suggests that product from those types of animals could be successfully marketed to both urban and rural consumers. The WTP data indicated that the consumer would pay for improved meat quality. The increased prices could be used to offset any extra costs involved in the production of a high-quality product graded on consumer palatability.

Recommendations

(i) The first recommendation from this study is that the extremes in processing be investigated in further experiments. The aim of the additional research would be to confirm that acceptable meat could be produced from pasture-finished Nguni bulls when delivered to slaughter with adequate reserves of glycogen and with the carcasses receiving the optimal amount of stimulation. This need be only a small study and in part could be used as a training exercise to embed consumer panels as a research tool in the development of a supply chain research project aimed at creating a niche market for product from cattle from smallholder farms in RSA.

(ii) Implicit in the first recommendation is a second recommendation that the consumer sensory protocol be adopted as a tool of preference to differentiate animal production and processing treatments and ultimate consumer satisfaction. The strong relationship between WTP data and quality grade indicated that industry efforts to improve eating quality should generate considerable additional revenue to overcome any increased costs of implementation.

(iii) This study clearly showed that sensory scores from both urban and rural consumers did not differ substantially. Both urban and rural groups indicated the same WTP for meat quality. Therefore, future experiments should investigate all avenues to improve meat quality from indigenous breeds. Certainly, by ensuring that no hormonal growth implants are used and that carcasses are processed under optimal conditions (i.e. good glycogen reserves at slaughter and the carcasses given optimal stimulation) good-quality meat should be obtained from older Nguni bulls. Other research, which was not part of the current study, indicates that other interventions such as tenderstretch, extended ageing, portioning of muscle and matching the optimal cooking styles to particular muscles, could also be used to improve eating quality and capture market share for a supply chain based on indigenous breeds.

(iv) Consideration should be given to undertaking a separate study focusing on meat grading and meat-marketing policies in South Africa, to assist the development of new beef markets based on consumer palatability preferences and animals from small-scale farmer herds finished on pasture.

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Appendixes

Appendix 1. Taste panel sheets and questionnaires

PRODUCT:

Tenderness

Not tender — Very tender

Juiciness

Not juicy — Very juicy

Liking of flavour

Dislike extremely — Like extremely

Overall liking

Dislike extremely — Like extremely

Please tick √ one of the following ☐ to rate the quality of the beef sample you have just eaten

Choose **one** only (you must make a choice).

- Unsatisfactory ☐
- Good everyday quality ☐
- Better than everyday quality ☐
- The best quality ☐

Date:_______________ City:___________________________

I.D. Number :_____________

Thank you for your participation today with our meat tasting.

Before you commence please listen to the instructions on how to use the scales contained in this questionnaire.

In between each sample please cleanse your palate by first taking a sip of diluted apple juice then chew a piece of bread and then take another sip of diluted apple juice.

We are after your opinion and therefore ask that you do not talk to any one else in the room during the research session.

Now just a few questions about yourself, please tick the appropriate box. (All this information is strictly confidential)

Demographic data

1) Please write down the suburb, town or village you normally live in:__________________

2) Age group (please tick 1 box)

<20 years	20–25 years	26–30 years	31–39 years	40–50 years	> 50 years
☐	☐	☐	☐	☐	☐

3) Gender (please tick 1 box)

Male ☐ **Female** ☐

4) What is the occupation of the main income earner in your household? (please tick 1 box)

Trades e.g. Plumber	Professional e.g. Teacher	Admin	Technical	Sales/ service	Labourer	Home duties	Student	Other employ-ment	Not employed
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

5) How often do you eat beef? (in any form such as steaks, roasts, stews, mince, kebabs, braai, sausages etc. Please tick 1 box)

Daily	4–5 times a week	2–3 times a week	Once per week	Once per two weeks	Once per month	Never eat beef
☐	☐	☐	☐	☐	☐	☐

6) How many people normally live in your household? (Adults are aged 18 years and over.)

	1	2	3	4	5	6	7	8 or more
Adults	☐	☐	☐	☐	☐	☐	☐	☐
Children	☐	☐	☐	☐	☐	☐	☐	☐

7) Please read the following statements and tick the <u>one statement</u> that applies to you

- ☐ **I enjoy red meat. It's an important part of my diet.**
- ☐ **I like red meat well enough. It's a regular part of my diet.**
- ☐ **I do eat some red meat although, truthfully, it wouldn't worry me if I didn't.**
- ☐ **I rarely/never eat red meat.**

8) When you eat beef, such as steaks, what level of cooking (or doneness) do you prefer? (please tick 1 box)

Almost raw ☐ **Rare** ☐ **Medium/rare** ☐

Medium ☐ **Medium/well done** ☐ **Well done** ☐

9) What level of income best categorises your combined gross household income? (please tick 1 box)

Up to R799 per month	R800 to R1,399 per month	R1,400 to R2,499 per month	R2,500 to R4,999 per month	R5,000 to R7,999 per month	R8,000 to R10,999 per month	R11,000 to R19,999 per month	More than R20,000 per month
☐	☐	☐	☐	☐	☐	☐	☐

10) What level of education have you reached? (please tick 1 box indicating the highest education level achieved)

Primary complete	Some high	Matriculation	Training certificate/s	University diploma/degree
☐	☐	☐	☐	☐

11) What is your home language? (please tick 1 box)

Afrikaans	English	IsiNdebele	IsiXhosa	IsiZulu	Sepedi
☐	☐	☐	☐	☐	☐

Sesotho	Setswana	SiSwati	Tshivenda	Xitsonga	Other
☐	☐	☐	☐	☐	☐

All information collected in this survey is strictly confidential.

Date:_______________ Group Name:_____________________________

I.D. Number :_____________

Based on the beef you just consumed: Please mark the line at the price per kg (rand (R)/kg) you believe best reflects the value for each category.

Unsatisfactory quality

R0/kg R10/kg R20/kg R30/kg R40/kg R50/kg R75/kg R100/kg R150/kg

Good everyday quality

R0/kg R10/kg R20/kg R30/kg R40/kg R50/kg R75/kg R100/kg R150/kg

Better than everyday quality

R0/kg R10/kg R20/kg R30/kg R40/kg R50/kg R75/kg R100/kg R150/kg

Premium quality

R0/kg R10/kg R20/kg R30/kg R40/kg R50/kg R75/kg R100/kg R150/kg

Are you the regular purchaser of beef for your family (please tick one box)?

Yes ☐ No ☐

How much do you typically spend on beef each week? R_______ per week

Approximately what percentage of your purchases would relate to the cooking styles below?

Mince __%
Sausage __%
Steak __%
Braai __%
Stew __%
Roast __%
Other __% ____________(Please specify what cooking style/s)
(Must total to 100%)

Appendix 2. Analyses of tenderness scores

Table A2.1. The analysis of variance (F ratios) for the effect of country, cooking method, supplier and consumer on tenderness score for the BLD096 and CHK078 samples

Independent variable	NDF, DDF[a]	BLD096	CHK078
Country	1, 56	1.04	**32.74**
Supplier (country)	2, 56	**36.68**	**8.26**
Cooking method (country)	1, 41	3.34	1.97
Consumer (country)	1, 41	0.07	**14.49**
Supplier × cooking method (country)	2, 56	0.36	0.83
Cooking method × consumer (country)	1, 41	1.13	2.14
Supplier × consumer (country)	2, 41	**3.66**	2.12

[a] N = numerator degrees of freedom; D = denominator degrees of freedom
Bold type F ratios are significant at *P*<0.05.

Table A2.2. Analysis of variance (F ratios) for the effect of country, cooking method, supplier, consumer and carcass side on tenderness score for the STR045 and TOP073 samples

Independent variable	NDF, DDF[a]	STR045	NDF, DDF	TOP073
Country	1, 118	0.33	1, 32	**23.84**
Supplier (country)	2, 118	**28.03**		
Cooking method (country)	1, 118	**10.56**	1, 32	0.03
Consumer (country)	1, 101	7.70	1, 15	1.64
Side	1, 101	1.34	1, 15	0.77
Supplier × cooking method (country)	2, 118	0.79		
Cooking method × consumer (country)	1, 101	0.10	1, 15	1.84
Supplier × consumer (country)	2, 101	1.16		
Side × supplier (country)	3, 110	**4.56**	1, 15	0.09

[a] N = numerator degrees of freedom; D = denominator degrees of freedom
Bold type F ratios are significant at *P*<0.05.

Table A2.3. Predicted means for tenderness score for the cooking method × consumer (country) interaction for the blade (BLD096), chuck (CHK078), striploin (STR045) and topside (TOP073) samples

Muscle	Cooking method		
	Consumer	Grilling	Slow cooking
BLD096	Rural (RSA)	54.7 (2.6)	57.2 (2.6)
	Urban (RSA)	52.8 (2.6)	60.4 (2.6)
	Australia	53.1 (2.8)	
CHK078	Rural (RSA)	**58.5 (2.7)**	**58.7 (2.7)**
	Urban (RSA)	**65.0 (2.7)**	**72.7 (2.7)**
	Australia	**45.2 (2.9)**	
STR045	Rural (RSA)	**62.3 (1.9)**	54.9 (1.9)
	Urban (RSA)	**66.1 (1.9)**	59.6 (1.9)
	Australia	**58.7 (3.2)**	
TOP073	Rural (RSA)	**45.6 (3.2)**	40.2 (3.2)
	Urban (RSA)	**36.9 (3.2)**	40.3 (3.2)
	Australia	**26.0 (2.3)**	

Bold type means within consumer group and muscle were significantly different for the different cooking methods (*P*<0.05).

Table A2.4. Predicted means for tenderness score for the supplier × cooking method (country) interaction for the blade (BLD096), chuck (CHK078) and striploin (STR045) samples

Muscle	Cooking method (country)	Supplier		
		Nguni	Bonsmara	Murray Grey
BLD096	Grilling (RSA)	33.7 (3.9)	60.8 (2.9)	**66.7 (3.9)**
	Slow cooking (RSA)	41.8 (4.4)	65.9 (2.9)	**68.8 (2.8)**
	Grilling (Australia)			**53.1 (2.8)**
CHK078	Grill (RSA)	**54.8 (4.4)**	71.6 (3.0)	**59.0 (2.8)**
	Slow cooking (RSA)	**63.0 (4.0)**	70.8 (3.0)	**63.2 (3.1)**
	Grilling (Australia)			**45.3 (4.4)**
STR045	Grill (RSA)	58.0 (2.6)	**59.8 (2.6)**	**74.7 (2.6)**
	Slow cooking (RSA)	53.4 (2.6)	**49.1 (2.6)**	**69.3 (2.6)**
	Grilling (Australia)			**58.7 (3.2)**

Bold type means within supplier and muscle were significantly different for the different cooking methods ($P<0.05$).

Table A2.5. Predicted means for tenderness score for the supplier × consumer (country) interaction for the blade (BLD096), chuck (CHK078) and striploin (STR045) samples

Muscle	Consumer	Supplier		
		Nguni	Bonsmara	Murray Grey
BLD096	Rural (RSA)	**42.4 (3.9)**	**59.4 (2.8)**	**66.0 (2.8)**
	Urban (RSA)	**33.0 (3.9)**	**67.3 (2.8)**	**69.5 (2.8)**
	Australia			**53.1 (2.8)**
CHK078	Rural (RSA)	**50.6 (4.1)**	**65.6 (2.9)**	**59.6 (2.9)**
	Urban (RSA)	**67.1 (4.1)**	**76.8 (2.9)**	**62.6 (2.9)**
	Australia			**45.3 (2.9)**
STR045	Rural (RSA)	**52.6 (2.3)**	**51.6 (2.3)**	**71.5 (2.3)**
	Urban (RSA)	**58.8 (2.3)**	**57.2 (2.3)**	**72.5 (2.3)**
	Australia			**58.7 (3.2)**

Bold type means within supplier and muscle were significantly different for the different consumer groups ($P<0.05$).

Table A2.6. Predicted means for tenderness score for the interaction between carcass side by supplier (country) for the blade (BLD096), chuck (CHK078) and striploin (STR045) samples

Muscle	Consumer	Supplier			
		Nguni	Bonsmara	Murray Grey (RSA)	Murray Grey (Australia)
STR045	Left	**51.9 (2.3)**	56.1 (2.3)	74.0 (2.3)	54.3 (4.8)
	Right	**59.5 (2.3)**	52.8 (2.3)	70.0 (2.3)	63.2 (4.3)
TOP073	Left	41.2 (2.3)			27.4 (3.4)
	Right	40.4 (2.3)			24.6 (3.1)

Bold type means within supplier and muscle were significantly different for the different side ($P<0.05$).

Appendix 3. Analyses of liking of flavour scores

Table A3.1. Analysis of variance (F ratios) for the effect of country, cooking method, supplier and consumer on liking of flavour score for the BLD096 and CHK078 samples

Independent variable	NDF, DDF[a]	BLD096	CHK078
Country	1, 56	**4.75**	0.13
Supplier (country)	2, 56	**16.82**	**10.99**
Cooking method (country)	1, 41	**7.13**	0.14
Consumer (country)	1, 41	0.03	**7.47**
Supplier × cooking method (country)	2, 56	2.84	2.62
Cooking method × consumer (country)	1, 41	0.13	**5.29**
Supplier × consumer (country)	2, 41	1.35	**3.23**

[a] N = numerator degrees of freedom; D = denominator degrees of freedom
Bold type F ratios are significant at $P<0.05$.

Table A3.2. Analysis of variance (F ratios) for the effect of country, cooking method, supplier, consumer and carcass side on liking of flavour score for the STR045 and TOP073 samples

Independent variable	NDF, DDF[a]	STR045	NDF,DDF	TOP073
Country	1,118	0.35	1,32	**1.24**
Supplier (country)	2,118	**20.88**	1,32	0.10
Cooking method (country)	1,118	**10.65**	1,15	0.16
Consumer (country)	1,101	0.96	1,15	1.21
Side	1,101	0.69	1,15	0.61
Supplier × cooking method (country)	2,118	**6.72**	1,15	1.09
Cooking method × consumer (country)	1,101	2.65		
Supplier × consumer (country)	2,101	**7.32**		
Side × supplier (country)	3,101	2.64		

[a] N = numerator degrees of freedom; D = denominator degrees of freedom
Bold type F ratios are significant at $P<0.05$.

Table A3.3. Predicted means for like flavour score for the interaction between cooking method and consumer (country) for the blade (BLD096), chuck (CHK078), striploin (STR045) and topside (TOP073) samples

Muscle	Consumer	Cooking method	
		Grilling	Slow cooking
BLD096	Rural (RSA)	53.2 (2.2)	58.7 (2.3)
	Urban (RSA)	52.0 (2.2)	59.0 (2.3)
	Australia	61.6 (2.4)	
CHK078	Rural (RSA)	58.8 (2.3)	**55.4 (2.2)**
	Urban (RSA)	59.8 (2.3)	**65.1 (2.2)**
	Australia	58.8 (2.4)	
STR045	Rural (RSA)	57.9 (1.5)	50.5 (1.5)
	Urban (RSA)	57.0 (1.5)	54.2 (1.5)
	Australia	56.6 (2.6)	
TOP073	Rural (RSA)	43.4 (3.6)	41.7 (3.6)
	Urban (RSA)	42.0 (3.6)	46.0 (3.6)
	Australia	39.8 (2.6)	

Bold type means within consumer group and muscle were significantly different for the different cooking methods ($P<0.05$).

Table A3.4. Predicted means for like flavour score for the supplier × cooking method (country) interaction for the blade (BLD096), chuck (CHK078) and striploin (STR045) samples

Muscle	Cooking method (country)	Supplier		
		Nguni	Bonsmara	Murray Grey
BLD096	Grilling (RSA)	**37.4 (3.4)**	59.2 (2.5)	61.1 (2.6)
	Slow cooking (RSA)	**52.4 (3.7)**	62.7 (2.5)	61.6 (2.4)
	Grilling (Australia)			61.6 (2.4)
CHK078	Grilling (RSA)	48.6 (4.0)	68.5 (2.7)	60.8 (2.5)
	Slow cooking (RSA)	58.4 (3.6)	66.5 (2.7)	55.8 (2.8)
	Grilling (Australia)			58.8 (2.4)
STR045	Grilling (RSA)	47.6 (1.9)	**58.6 (1.9)**	**66.3 (1.9)**
	Slow cooking (RSA)	50.5 (1.9)	**50.2 (1.9)**	**56.4 (1.9)**
	Grilling (Australia)			**56.6 (2.6)**

Bold type means within supplier and muscle were significantly different for the different cooking methods (*P*<0.05).

Table A3.5. Predicted means for like flavour score for the supplier × consumer (country) interaction for the blade (BLD096), chuck (CHK078) and striploin (STR045) samples

Muscle	Consumer	Supplier		
		Nguni	Bonsmara	Murray Grey
BLD096	Rural (RSA)	45.6 (3.4)	59.0 (2.4)	63.2 (2.4)
	Urban (RSA)	44.2 (3.4)	62.9 (2.4)	59.5 (2.4)
	Australia			61.6 (2.4)
CHK078	Rural (RSA)	**49.5 (3.4)**	**62.9 (2.4)**	58.8 (2.4)
	Urban (RSA)	**57.5 (3.4)**	**72.1 (2.4)**	57.8 (2.4)
	Australia			58.8 (2.4)
STR045	Rural (RSA)	**46.0 (1.8)**	52.2 (1.8)	64.5 (1.8)
	Urban (RSA)	**52.1 (1.8)**	56.6 (1.8)	58.2 (1.8)
	Australia			56.6 (2.6)

Bold type means within supplier and muscle were significantly different for the different consumer groups (*P*<0.05).

Table A3.6. Predicted means for like flavour score for the carcass side × supplier (country) interaction for the blade (BLD096), chuck (CHK078) and striploin (STR045) samples

Muscle	Consumer	Supplier			
		Nguni	Bonsmara	Murray Grey (RSA)	Murray Grey (Australia)
STR045	Left	**46.3 (1.8)**	54.9 (1.8)	63.2 (1.84)	54.0 (3.9)
	Right	**51.8 (1.8)**	53.8 (1.8)	59..5 (1.8)	59.1 (3.5)
TOP073	Left	46.7 (2.6)			39.9 (3.8)
	Right	39.9 (2.6)			39.7 (3.4)

Bold type means within supplier and muscle were significantly different for the different side (*P*<0.05).

Appendix 4. Analyses of juiciness scores

Table A4.1. Analysis of variance (F ratios) for the effect of country, cooking method, supplier and consumer on juiciness score for the BLD096 and CHK078 samples

Independent variable	NDF, DDF[a]	BLD096	CHK078
Country	1, 56	3.65	1.26
Supplier (country)	2, 56	**5.97**	1.65
Cooking method (country)	1, 41	3.26	6.25
Consumer (country)	1, 41	0.70	**32.11**
Supplier × cooking method (country)	2, 56	0.73	0.30
Cooking method × consumer (country)	1, 41	**2.26**	**8.03**
Supplier × consumer (country)	2, 41	1.83	**3.26**

[a] N = numerator degrees of freedom; D = denominator degrees of freedom
Bold type F ratios are significant at $P<0.05$

Table A4.2. Analysis of variance (F ratios) for the effect of country, cooking method, supplier, consumer and carcass side on juiciness scores for the STR045 and TOP073 samples

Independent variable	NDF, DDF[a]	STR045	NDF,DDF	TOP073
Country	1, 118	0.66	1,32	**14.79**
Supplier (country)	2, 118	2.29		
Cooking method (country)	1, 118	**76.70**	1,32	**20.57**
Consumer (country)	1, 101	**13.80**	1,15	0.05
Side	1, 101	0.30	1,15	0.99
Supplier × cooking method (country)	2, 118	1.19		
Cooking method × consumer (country)	1, 101	0.17	1,15	0.03
Supplier × consumer (country)	2, 101	2.15		
Side × supplier (country)	3, 101	1.07	1,15	0.05

[a] N = numerator degrees of freedom; D = denominator degrees of freedom
Bold type F ratios are significant at $P<0.05$.

Table A4.3. Predicted means for juiciness score for the cooking method × consumer (country) interaction for the blade (BLD096), chuck (CHK078), striploin (STR045) and topside (TOP073) samples

Muscle	Consumer	Cooking method	
		Grilling	Slow cooking
BLD096	Rural (RSA)	58.1 (2.5)	48.5 (2.5)
	Urban (RSA)	55.4 (2.5)	54.5 (2.5)
	Australia	59.9 (2.6)	
CHK078	Rural (RSA)	**65.0 (2.3)**	**53.0 (2.3)**
	Urban (RSA)	**71.9 (2.3)**	**72.3 (2.3)**
	Australia	**62.5 (2.5)**	
STR045	Rural (RSA)	58.5 (1.5)	43.4 (1.5)
	Urban (RSA)	63.2 (1.5)	29.3 (1.5)
	Australia	55.9 (2.7)	
TOP073	Rural (RSA)	50.6 (3.5)	34.1 (3.5)
	Urban (RSA)	50.8 (3.5)	35.5 (3.5)
	Australia	31.1 (2.5)	

Bold type means within consumer group and muscle were significantly different for the different cooking methods ($P<0.05$)

Table A4.4. Predicted means for juiciness score for the supplier × cooking method (country) interaction for the blade (BLD096), chuck (CHK078) and striploin (STR045) samples

Muscle	Cooking method (country)	Supplier		
		Nguni	Bonsmara	Murray Grey
BLD096	Grilling (RSA)	48.5 (4.1)	**62.9 (3.1)**	58.8 (3.3)
	Slow cooking (RSA)	43.8 (4.6)	**53.7 (3.1)**	57.0 (2.9)
	Grilling (Australia)			59.9 (2.6)
CHK078	Grill(RSA)	67.0 (3.7)	70.5 (2.5)	**67.9 (2.3)**
	Slow cooking (RSA)	62.5 (3.3)	65.7 (2.5)	**59.7 (2.6)**
	Grilling (Australia)			**62.5 (2.5)**
STR045	Grilling (RSA)	60.5 (2.0)	**57.3 (2.0)**	**64.7 (2.0)**
	Slow cooking (RSA)	46.8 (2.0)	**45.5 (2.0)**	**46.8 (2.0)**
	Grilling (Australia)			**55.9 (2.7)**

Bold type means within supplier and muscle were significantly different for the different cooking methods (*P*<0.05).

Table A4.5. Predicted means for juiciness score for the supplier × consumer (country) interaction for the blade (BLD096), chuck (CHK078) and striploin (STR045) samples

Muscle	Consumer	Supplier		
		Nguni	Bonsmara	Murray Grey
BLD096	Rural (RSA)	47.2 (3.8)	54.9 (2.6)	57.7 (2.7)
	Urban (RSA)	45.1 (3.8)	61.7 (2.6)	58.1 (2.7)
	Australia			59.9 (2.6)
CHK078	Rural (RSA)	**56.9 (3.5)**	**59.2 (2.5)**	60.9 (2.5)
	Urban (RSA)	**72.6 (3.5)**	**77.1 (2.5)**	66.7 (2.5)
	Australia			62.5 (2.5)
STR045	Rural (RSA)	**49.9 (1.9)**	**47.9 (1.9)**	55.1 (1.9)
	Urban (RSA)	**57.4 (1.9)**	**54.9 (1.9)**	56.3 (1.9)
	Australia			55.9 (2.7)

Bold type means within supplier and consumer group were significantly different for the different cooking methods (*P*<0.05).

Table A4.6. Predicted means for juiciness score for the carcass side × supplier(country) interaction for the blade (BLD096), chuck (CHK078) and striploin (STR045) samples

Muscle	Consumer	Supplier			
		Nguni	Bonsmara	Murray Grey (RSA)	Murray Grey (Australia)
STR045	Left	**52.5 (1.9)**	52.0 (1.9)	57.1 (1.9)	53.3 (4.0)
	Right	**54.8 (1.9)**	50.9 (1.9)	54.4 (1.9)	58.5 (3.6)
TOP073	Left	44.6 (2.5)			32.3 (3.7)
	Right	40.9 (2.5)			29.9 (3.3)

Bold type means within supplier and muscle were significantly different for the different side (*P*<0.05).

Appendix 5. Analyses of overall liking scores

Table A5.1. Analysis of variance (F ratios) for the effect of country, cooking method, supplier and consumer on overall liking score for the BLD096 and CHK078 samples

Independent variable	NDF, DDF[a]	BLD096	CHK078
Country	1, 56	0.88	**8.34**
Supplier (country)	2, 56	**24.80**	**8.41**
Cooking method (country)	1, 56	3.25	0.22
Consumer (country)	1, 41	0.85	**6.84**
Supplier × cooking method (country)	2, 56	2.53	0.46
Cooking method × consumer (country)	1, 41	1.23	2.45
Supplier × consumer (country)	2, 41	0.91	**4.55**

[a] N = numerator degrees of freedom; D = denominator degrees of freedom
Bold type F ratios are significant at *P*<0.05.

Table A5.2. Analysis of variance (F ratios) for the effect of country, cooking method, supplier, consumer and carcass side on overall liking score for the STR045 and TOP073 samples

Independent variable	NDF, DDF[a]	STR045	NDF,DDF	TOP073
Country	1, 118	0.33	1,32	**7.29**
Supplier (country)	2, 118	**28.07**		
Cooking method (country)	1, 118	**22.14**	1,32	0.17
Consumer (country)	1, 101	0.68	1,15	0.08
Side	1, 101	0.39	1,15	0.30
Supplier × cooking method (country)	2, 118	**7.47**		
Cooking method × consumer (country)	1, 101	0.02	1,15	3.13
Supplier × consumer (country)	2, 101	**7.15**		
Side × supplier (country)	3, 101	2.53	1,15	0.80

[a] N = numerator degrees of freedom; D = denominator degrees of freedom
Bold type F ratios are significant at *P*<0.05.

Table A5.3. Predicted means for overall liking score for the cooking method × consumer (country) interaction for the blade (BLD096), chuck (CHK078), striploin (STR045) and topside (TOP073) samples

Muscle	Consumer	Cooking method	
		Grilling	Slow cooking
BLD096	Rural (RSA)	**56.6 (2.3)**	58.4 (2.3)
	Urban (RSA)	**51.9 (2.3)**	58.6 (2.3)
	Australia	**58.9 (2.5)**	
CHK078	Rural (RSA)	**60.4 (2.4)**	**58.2 (2.3)**
	Urban (RSA)	**62.9 (2.4)**	**67.4 (2.3)**
	Australia	**54.2 (2.5)**	
STR045	Rural (RSA)	59.1 (1.5)	51.5 (1.5)
	Urban (RSA)	60.2 (1.5)	52.9 (1.5)
	Australia	57.5 (2.7)	
TOP073	Rural (RSA)	46.6 (3.5)	39.1 (3.5)
	Urban (RSA)	39.6 (3.5)	44.2 (3.5)
	Australia	34.3 (2.5)	

Bold type means within consumer group and muscle were significantly different for the different cooking methods (*P*<0.05)

Table A5.4. Predicted means for overall liking score for the supplier × cooking method (country) interaction for the blade (BLD096), chuck (CHK078) and striploin (STR045) samples

Muscle	Cooking method (country)	Supplier		
		Nguni	Bonsmara	Murray Grey
BLD096	Grilling (RSA) Slow cooking (RSA) Grilling (Australia)	**37.0 (3.3)** **49.4 (3.7)**	63.6 (2.5) 62.3 (2.5)	62.1 (2.6) 63.8 (2.4) 58.9 (2.5)
CHK078	Grilling (RSA) Slow cooking (RSA) Grilling (Australia)	53.9 (3.9) 58.8 (3.5)	69.3 (2.6) 68.4 (2.6)	61.8 (2.5) 61.2 (2.8) 54.2 (2.5)
STR045	Grilling (RSA) Slow cooking (RSA) Grilling (Australia)	49.0 (1.9) 50.2 (1.9)	**60.6 (1.9)** **48.0 (1.9)**	**69.2 (1.9)** **58.4 (1.9)** 57.5 (2.7)

Bold type means within supplier and muscle were significantly different for the different cooking methods (*P*<0.05).

Table A5.5. Predicted means for overall liking score for the supplier × consumer (country) interaction for the blade (BLD096),chuck (CHK078) and striploin (STR045) samples

Muscle	Consumer	Supplier		
		Nguni	Bonsmara	Murray Grey
BLD096	Rural(RSA) Urban(RSA) Australia	46.3 (3.5) 40.4 (3.5)	62.0 (2.5) 63.8 (2.5)	64.0 (2.5) 61.9 (2.5) 58.9 (2.5)
CHK078	Rural(RSA) Urban(RSA) Australia	50.5 (3.5) 62.2 (3.5)	64.4 (2.5) 73.2 (2.5)	63.0 (2.5) 59.9 (2.3) 54.2 (2.5)
STR045	Rural(RSA) Urban(RSA) Australia	**46.3 (1.9)** **52.9 (1.9)**	52.6 (1.9) 56.1 (1.9)	**67.1 (1.9)** **60.6 (1.9)** **57.5 (2.7)**

Bold type means within supplier and consumer were significantly different for the different cooking methods (*P*<0.05).

Table A5.6. Predicted means for overall liking score for the carcass side × supplier (country) interaction for the blade (BLD096), chuck (CHK078) and striploin (STR045) samples

Muscle	Consumer	Supplier (country)			
		Nguni (RSA)	Bonsmara (RSA)	Murray Grey (RSA)	Murray Grey (Australia)
STR045	Left Right	**46.8 (1.9)** **52.4 (1.9)**	55.4 (1.9) 53.2 (1.9)	65.4 (1.9) 62.3 (1.9)	55.5 (4.0) 59.5 (4.0)
TOP073	Left Right	44.6 (2.5) 40.2 (2.5)			33.8 (3.7) 34.8 (3.3)

Bold type means within supplier and muscle were significantly different for the different side (*P*<0.05).