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Effect of gender on the meat quality characteristics and chemical composition of kudu (*Tragelaphus strepsiceros*), an African antelope species

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Abstract

The kudu (*Tragelaphus strepsiceros*), one of Africa's most majestic antelope species, shows a strong sexual dimorphism. The male reaches a larger size (≈250 kg live weight) than the female (≈180 kg live weight). Kudu occur throughout the savannah regions in central Africa, south of the equatorial forests, through East Africa to Ethiopia, Sudan and Chad down to the Eastern Cape (South Africa). Kudu are predominantly browsers, but will occasionally graze. Within South Africa, this species is hunted regularly for local consumption, and Kudu meat is also a regular item in most restaurants that serve game meat and is also frequently exported. However, very little data has been published pertaining to the muscle chemical composition and other quality attributes of its meat. In the present investigation, the proximate, amino acid, fatty acid and mineral chemical compositions of the *Longissimus dorsi et lumborum* muscle of 18 animals are presented, and the effect of gender thereupon tested by means of standard student's *t*-tests. Kudu meat has a high protein and a low fat content. Only two of the longer chained polyunsaturated fatty acids (C20:3*n*−6 and C20:5*n*−3) differed between the females and males, the latter having a higher concentration each time. Of the kudu muscle's fatty acids, 37% were saturated, 22% monounsaturated and 41% polyunsaturated. The mean PUFA to SFA ratio (1.12) was well above the recommended 0.45 prescribed by the British Department of Health. The *n*−6:*n*−3 PUFA ratio (2.34) was also well below the British Department of Health's recommended figure of four. Histidine and valine had significantly higher levels in female kudu meat than in male kudu meat. Phosphorus was present at the highest concentrations in both female and male animals. Overall, the chemical composition of kudu meat is not significantly effected by gender.
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Keywords: Game meat; Chemical composition; Meat quality; Fatty acid; Amino acids; Mineral content

1. Introduction

During the past 20–25 years the commercial utilisation of wildlife has grown tremendously in South Africa (Hoffman & Bigalke, 1999). Berry (1986) compared the different aspects of utilisation on a wildlife farming enterprise and noted that wildlife can be utilised in either a consumptive or a non-consumptive way. Consumptive utilisation includes trophy hunting, recreational hunting, live capture and sales and game meat production. Non-consumptive utilisation is the provision of services to tourists, such as game viewing, bird watching and wildlife photography. Non-consumptive utilisation is also better known as ecotourism. When comparing the four pillars of consumptive utilisation, trophy hunting gives the highest net return on capital. This is followed by biltong or recreational hunting, live sales and lastly game meat production. However, when one considers the low percentage of trophy animals on a particular game ranch, trophy hunting gives the lowest return per unit area. Live sales of game are a good option, but in recent years auction prices for the more common wildlife species have reached a plateau (Eloff, 2002). In Limpopo Province, the heads of game sold increased from

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6802 in 2003 to 9163 in 2004. However, the monetary value decreased from 39 million Rand in 2003 to 35 million Rand in 2004 (Eloff, 2005).

The time has come when the wildlife industry can no longer depend on hunting and live sales alone. Diversification into other areas for profitable production has to be considered. Although game meat is already marketed locally and internationally, there is great potential for the expansion of target markets. In 2000, a survey in the Northern Province, South Africa, showed that game meat production contributed only 4% to the wildlife industry in that Province (Van Der Waal & Dekker, 2000).

In order to conserve wildlife and wildlife habitats, game ranches and/or nature reserves need to be managed from a sustainable utilisation viewpoint. The consequence is that surplus animals have to be removed every year, by hunting, harvesting or capture for live sales.

The driving force behind game meat for export is the demand for meat derived from species such as springbok (*Antidorcas marsupialis*), kudu, gemsbok (*Oryx gazelle*) and impala (*Aepyceros melampus*) by European countries (Olivier & Van Zyl, 2002). There is also a definite growth in game meat consumption through the local South African hotel and restaurant trade (Hoffman, Crafford, Muller, & Schutte, 2003). A survey of European tourists found that 92% had eaten game meat in South African restaurants. Kudu, springbok and warthog (*Phacochoerus africanus*) are the species commonly consumed by tourists (Hoffman, 2003). Jansen Van Rensburg (2001) reported that the demand for game meat is expected to grow, both locally and internationally, as game meat meets the modern consumer's demand for lean meat.

To compete with existing meat products, scientifically based information on the quality and characteristics of game meat is needed. The same criterion that applies to meat production from domestic stock, applies to game meat production. Such criteria include carcass yield, chemical composition and meat quality. Factors affecting meat quality, such as species, age, sex, geographical region and cropping method, also need to be evaluated.

The kudu is considered by many to be one of the most beautiful and majestic antelope species in Africa. With shoulder heights ranging from 100 to 150 cm, the greater kudu is also one of the tallest of the antelope species. There is a definite sexual dimorphism between male and female kudu; the female has a mean body weight of 170 kg (120–215 kg), whereas the mean body weight for the male is 257 kg (120–315 kg) (Estes, 1991). The male kudu has the largest horns in the genus *Tragelaphus*, with a mean length of 120 cm, but also known to reach lengths of up to 180 cm (Estes, 1991). Kudu are browsers, feeding on shrubs, fruit and seed pods and will raid crops where available (Walker, 1996).

All over eastern and southern Africa, kudu have been hunted for many years and the meat utilised as a food source. However, little is known about the chemical composition and quality of its meat. The question of whether gender plays a role in the quality of kudu meat has also not been answered.

2. Materials and methods

In this study, 18 kudu (8 males and 10 females) were harvested in the Tussen die Riviere Nature Reserve in the Free State Province, South Africa. All animals were harvested using standard techniques. The animals were killed instantaneously with head shots using a .270 calibre rifle. Carcasses were bled, eviscerated, skinned and cleaned, after which they were moved to a cooling facility. The next day (≈36 h post-mortem) the *Longissimus dorsi et lumborum* muscle (MLD) was removed from between the 12th and 13th rib to between the 4th and 5th lumber vertebrae. The pH was measured in the MLD with a calibrated (standard buffers at pH 4.0 and pH 7.0) Crison 506 portable pH meter. Physical quality characteristics of the fresh meat and the chemical composition (conducted on frozen samples) of the MLD were analysed and the data subjected to the student's *t*-test.

Drip loss was determined by taking a freshly cut sample of 80–100 g meat, weighing it and then suspending it in an inflated plastic bag (Honikel, 1998). The sample bags were then left in a cold room at 1–5 °C for 24 h and then weighed again. The drip loss is expressed as a percentage of the weight of the fresh sample. Cooking loss was determined by using freshly cut samples of υ 80 g weighing and placing in separate plastic bags. The sealed plastic bags were cooked in a water bath at 80 °C for 1 h. The samples were then cooled under running water, the liquid decanted and the samples weighed. The cooking loss is expressed as a percentage of the initial weight (Honikel, 1998). The cooked samples were then used to determine the tenderness by measuring Warner–Bratzler shear force values. At least three cores of 1.27 cm were taken from each sample steak with a hand-coring device (Byrne, Troy, & Buckley, 2000). A Warner–Bratzler shear device, with a V-shaped blade that is attached to an instron universal testing machine, was used to take the shear force (*N*) measurements (Byrne et al., 2000).

The remaining MLD samples were vacuum-packed, frozen and stored at −20 °C until analysed chemically. Prior to analyses, the samples were defrosted and homogenised. The moisture and protein contents (g/100 g meat) of all the samples were determined according to the association of official analytical chemist's standard techniques (AOAC, 1997). The accuracy and repeatability of all the techniques were controlled on a bi-monthly basis by means of a National Inter-laboratory scheme (AgriLASA: Agricultural Laboratory Association of South Africa) wherein blind samples were analysed. The moisture content was determined by drying at 105 °C for 24 h. To determine the protein content, dried and defatted meat samples were ground with a pestle in a mortar to a fine powder. The samples of 100 mg were inserted into a foil wrap designed for the Leco protein analyser (Leco Fp-528). The nitrogen con-

tent was multiplied by 6.25 to calculate the protein concentration in the sample. An EDTA calibration sample (LECO Corporation, 3000 Lake View Ave., St. Joseph, HI 49085-2396, USA, Part number 502-092, lot number 1038) was analysed with each batch of samples to ensure accuracy and recovery rate. The fat content was determined by homogenising the samples in a blender, followed by chloroform:methanol (2:1) extraction (Lee, Trevino, & Chaiyawat, 1996).

The amino acid composition was determined by using a modification of the HPLC method described by Bidlingmeyer, Cohen, and Tarvin (1984). The meat was defatted by solvent extraction, according to the method of Lee et al. (1996) and then hydrolysed with 6 N HCl in a vacuum-sealed tube for 24 h at 110 °C, centrifuged and dried under vacuum for at least 1.5 h. The pH was adjusted by adding 20 µl ethanol:water:triethylamine (2:2:1) and the sample dried as before. The samples were derivatised by adding 20 µl ethanol:water:triethylamine:phenylisothiocyanate (7:1:1:1) at room temperature (26 °C) for 10 min and then dried under vacuum for at least 3 h. The sample was re-suspended in 200 µl Picotag (Waters, Millford, MA, USA), from which 8 µl were then injected into an HPLC (Waters HPLC column, Novapak C18. 60 Angstrom, 4 µm, 3.9 × 150 mm). Separation was by using buffers: A (sodium acetate, pH 6.4, 5000 ppm EDTA, triethylamine (1:2000) and 6%, v/v, acetonitrile) and B (60%, v/v, acetonitrile and 5000 ppm EDTA). A 1525 HPLC with a binary gradient delivery, 717 auto-sampler and injector, 1500 column heater and 2487 dual wavelength UV detector were the equipment used in the analysis by Breeze software Z (Waters, Milford, MA, USA). Accuracy and repeatability of this analysis is ensured by the inclusion of a control sample of known amino acid composition with the samples prior to hydrolysis.

The mineral composition of the meat was determined after ashing the defatted meat samples. The defatted meat samples (1– 3 g) were air-dried and ground to pass through a 0.5–1.0 mm sieve. Thereafter, the samples were ashed overnight in a muffle furnace at 550 °C. A 6 M hydrochloric acid (HCI) solution was prepared by diluting 500 cm^3 of a 36% (m/m) HCI solution to 1 dm^3. After ashing, 5 cm^3 of a 6 M HCI was added to dissolve the cooled sample. Thereafter, the samples were dried on a waterbath. After cooling, a 5 cm^3 6 M nitric acid (HNO_3) solution was added to the samples. The 6 M HNO_3 solution was prepared by diluting 429 cm^3 of a 65% (m/m) solution to 1 dm^3. After adding the latter solution, the samples were heated on a waterbath and removed after boiling point was reached. The solution was subsequently filtered through a filter paper into a 100 cm^3 volumetric flask and diluted to volume with deionized water (Giron, 1973). Element concentrations were then measured on an ICP-Thermo Jarrel Ash, IRIS (AP).

The fatty acid content was determined by using the method of Tichelaar, Smuts, Van Stuiivenberg, Faber, and Benadé (1998). After thawing the meat, the lipids in a 2 g sample were extracted with chloroform/methanol (2:1) and 0.01% (v/v) butylated hydroxytoluene (BHT) as the antioxidant. The samples were homogenised for 30 s in a polytron mixer (Kinematica, type PT 10–35, Switzerland) and transmethylated for 2 h at 70 °C with methanol/sulphuric acid (19:1; v/v). After cooling to room temperature, the fatty acid methyl esters (FAME) were extracted with water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen. The FAME were purified by TLC (silica gel 60 plates) and analysed by GLC (Varian Model 3300, equipped with a flame ionisation detector), using a 60 m BPX70 capillary column of 0.25 mm internal diameter (SGE, Australia). The hydrogen gas flow rate was 25 ml/min; and the hydrogen carrier gas rate 2–4 ml/min. Temperature programming was linear at 3 °C/min, with an initial temperature of 150 °C, a final temperature of 220 °C, an injector temperature of 240 °C and a detector temperature of 250 °C. Heptadecanoic acid (C17:0) was used as an internal standard (catalogue number H3500, Sigma–Aldrich Inc. 595 North Harrison Road, Bellefonte, PA 16823-0048, USA). The FAME in the total lipids were identified by comparison of the retention times with those of a standard FAME mixture (SuplecoTM 37 Component FAME Mix, Catalogue number 18919-1AMP, Lot number, LB-16064. Sigma–Aldrich Inc. North Harrison Road, Bellefonte, PA 16823-0048, USA).

3. Results and discussion

3.1. Physical characteristics

No significant differences in the live weight (120.80 ± 10.36 vs. 134.13 ± 4.81 kg) and the carcass weight (72.40 ± 6.68 vs. 79.25 ± 4.21 kg) of female and male kudus were detected. The lack of differences in weights between female and male kudu is due to the fact that no heavy trophy bulls were culled. Presently, neither age (with the exception of mature male trophy bulls and young calves) nor gender is taken into account when harvesting this species (Hoffman & Wiklund, 2006). The age of the animals used in this investigation was not determined. Dress out percentages for female and male kudu were 59.75 ± 0.99% and 58.86 ± 1.46%, respectively. This compares favourably with the dress out percentage for kudu (56.6%) in a study by Huntley (1971) on 18 kudu in the Northern Transvaal (now the Limpopo Province), South Africa. The slightly

Table 1
The physical measurements of *Longissimus dorsi et lumborum* muscle in female and male kudu

Physical measurements	Female ($n = 10$)	Male ($n = 8$)	$Pr > \|t\|$
pH	5.43 ± 0.02	5.40 ± 0.02	0.083
Drip loss (%)	4.48 ± 0.53	3.71 ± 0.15	0.226
Cooking loss (%)	38.36 ± 1.21	41.17 ± 1.21	0.140
Shear force (N)	140.01 ± 7.33	136.63 ± 11.24	0.810

lower dress out percentage of the bulls could be attributed to the weight of their horns.

The physical characteristics of female and male kudu meat (Table 1) showed no significant differences. The mean pH for the group was 5.37 ± 0.02. The mean drip loss was 4.48 ± 0.53% for female and 3.71 ± 0.15% for male kudu. The drip loss values from this study were higher than those obtained for night-cropped impala (Hoffman, 2000). However, the drip loss values for female and male impala were also found to be similar (2.66 ± 1.097% and 2.45 ± 1.362%, respectively; Hoffman (2000). Cooking loss values for female (23.48 ± 1.449%) and male (24.48 ± 1.388%) impala (Hoffman, 2000) were also lower than the values for female (38.36 ± 1.21%) and male (41.17 ± 1.21%) kudu from the present study. Shear force values showed no significant differences between male (136.63 ± 11.24 N) and female (140.01 ± 7.33140.01 ± 7.33 N) kudu.

3.2. Proximate composition

The proximate composition of the *Longissimus dorsi* muscle of female and male kudu is represented in Table 2. No significant differences ($P > 0.05$) were detected between female and male proximate compositions. The high protein content in both female (24.3 ± 0.278%) and male (23.6 ± 0.181%) kudu meat is of importance from a health point of view. Although it seems that the protein content differs significantly between female and male kudu, this can be due to the cumulative effect of the percentages. The fat content is also very low (female: 1.56 ± 0.093%, male: 1.58 ± 0.056%), which indicates that kudu meat can be considered as a healthy, lean meat.

3.3. Fatty acids

The fatty acid content (%) of kudu MLD is shown in Table 3. Fatty acids not detected were C22:0 (docosanoic acid), C22:4*n*−6, C24:0 (tetracosanoic acid) and C24:1*n*−9 (15-tetracosenoic acid). Oleic acid (C18:1), a monounsaturated fatty acid (MUFA), was found to be most abundant in the female (21.9 ± 1.46%) while linoleic acid (C18:2 *n*−6), a polyunsaturated fatty acid (PUFA), constituted the biggest proportion of fatty acids in the male kudu (20.5 ± 0.786%). The fatty acids present in the highest proportions (in descending order) were oleic, stearic, linoleic and palmitic acid.

Table 2
Proximate composition of *Longissimus dorsi et lumborum* muscle in female ($n = 10$) and male ($n = 8$) kudu

Chemical constituents (%)	Female ($n = 10$)	Male ($n = 8$)	$Pr > \|t\|$
Moisture	74.14 ± 0.285	74.49 ± 0.162	0.342
Protein	24.3 ± 0.278	23.6 ± 0.181	0.059
Fat	1.56 ± 0.093	1.58 ± 0.056	0.880
Ash	1.29 ± 0.021	1.23 ± 0.032	0.090

Table 3
The mean fatty acid content (%) of *Longissimus dorsi et lumborum* muscle in female and male kudu

Fatty acid (%)	Female ($n = 10$)	Male ($n = 8$)	$Pr > \|t\|$
C16:0	17.5 ± 0.688	16.1 ± 0.343	0.106
C18:0	20.0 ± 1.16	19.7 ± 1.09	0.864
C20:0	0.20 ± 0.035	0.11 ± 0.042	0.115
Total SFA (%)	*37.7*	*35.9*	0.433
C16:1*n*−7	0.69 ± 0.129	0.52 ± 0.054	0.264
C18:1*n*−9	21.9 ± 1.46	19.91 ± 0.967	0.287
C20:1*n*−9	0.10 ± 0.030	0.06 ± 0.033	0.331
Total MUFA (%)	*22.74*	*20.48*	0.270
C18:2*n*−6	19.0 ± 1.31	20.5 ± 0.786	0.370
C18:3*n*−3	4.67 ± 0.383	4.85 ± 0.395	0.746
C18:3*n*−6	0.08 ± 0.028	0.05 ± 0.026	0.477
C20:2*n*−6	0.12 ± 0.032	0.15 ± 0.083	0.723
C20:3*n*−6	0.92 ± 0.049	1.14 ± 0.050	0.008
C20:4*n*−6	7.74 ± 0.455	8.44 ± 0.376	0.270
C20:5*n*−3	2.50 ± 0.256	3.17 ± 0.147	0.049
C22:5*n*−3	2.42 ± 0.150	2.75 ± 0.139	0.135
C22:6*n*−3	2.06 ± 0.239	2.50 ± 0.227	0.202
Total PUFA (%)	*39.53*	*43.6*	0.175
PUFA: SFA	1.09	1.23	0.344
n−6: *n*−3	2.42	2.29	0.228

The fatty acid content of MLD in female and male kudu differed significantly only in two of the polyunsaturated fatty acids (C20:5*n*−3 and C20:3*n*−6). In both cases, the male had a higher concentration of the polyunsaturated fatty acids (PUFA). Other polyunsaturated fatty acids present in high quantities were linoleic acid, arachidonic acid and α-linolenic acid. In the present study PUFAs represent the highest proportion of fatty acids in both female (39.5%) and male (43.6%) kudu MLD. The high levels of PUFAs can be attributed to the fact that the kudu is a browser, feeding on trees and shrubs. Wiklund, Pickova, Sampels, & Lundström (2001) studied reindeer fed on different commercial feeds compared with grazing animals. The meat from the grazing reindeer had a higher *n*−3 PUFA content. In the kudu muscle analysed, the *n*−6:*n*−3 ratio was found to be 2.42 for females and 2.29 for males ($P > 0.05$).

Myristic (C14:0) and palmitic (C16:0) acids are said to be the principal fatty acids that cause an increase in blood cholesterol levels. Stearic acid (C18:0) is considered a desirable fatty acid as it is converted to oleic acid in the human body (Bender, 1992). Eicosapentaenoic acid (C20:5*n*−3) and dihomo-γ-linolenic acid (C20:3*n*−6) are both long-chain PUFAs known to play an important role in human health. C20:5*n*−3 is known to be beneficial in protection against cardiovascular diseases because of lipid-lowering effects and reduction of platelet aggregation (Sayanova & Napier, 2004). Eicosapentaenoic acid (EPA) is also the precursor of docosahexaenoic acid (DHA) and together they are important for normal cognitive and behavioural functions. An individual's receptiveness to cardiovascular diseases might also be lowered with a high ratio of unsaturated fatty

acids (UFA) to saturated fatty acids (SFA) in the diet (Lawrie, 1998). In the male kudu's muscle, 64.1% were UFA's and 35.9% were SFA's. The ratio for female kudu was 62.3% unsaturated to 37.7% saturated fatty acids. The British Department of Health recommends a PUFA:SFA ratio of over 0.4. The PUFA:SFA ratio in kudu meat was calculated to be 1.05 for female and 1.21 for male animals. In a study by Enser, Hallet, Hewett, Fursey, & Wood (1996), the PUFA:SFA concentrations for beef, lamb, and pork were 0.11, 0.15 and 0.58, respectively. When compared with the domesticated animals in that study, the female and male kudu had more favourable PUFA:SFA ratios.

Although the kudu muscle had a low total lipid content (<2% Table 2) and would thus have a minimal effect on total fat consumed, its contribution to the composition of human dietary fat intake is still of importance. The recommended maximum $n-6$:$n-3$ ratio according to the British Department of Health is four. The mean for female and male kudu is 2.34 which is well below the maximum of four. Due to the desirable $n-6$:$n-3$ and PUFA:SFA ratios, kudu meat can be seen as a favourable meat for human consumption. Also, the mean desirable fatty acid (stearic acid plus all unsaturated fatty acids) content of kudu meat is very high at 83%. Wood et al. (2003) found that the feeding of grass or roughage had the effect of producing higher concentrations of $n-3$ PUFAs, whereas feeding of concentrates led to a higher $n-6$ PUFA production. Wiklund et al. (2001) showed that the fatty acid composition of reindeer grazing on natural pastures had a higher $n-3$ PUFA content than had that of reindeer fed on pellets. The kudu, being a browser and therefore consuming mostly roughage, will have a high $n-3$ PUFA concentration in its muscles, as was found in this study.

3.4. Amino acids

The amino acid composition of the MLD of the kudu is represented in Table 4. All essential amino acids were present in higher concentrations in female muscle than in male muscle. However, only two of the essential amino acids showed significant differences ($P < 0.05$) between the female and the male. Histidine, the precursor of histamine, was found to be present at a concentration of 0.93 ± 0.016 g/100 g muscle in female compared to the concentration of 0.86 ± 0.012 g/100 g muscle in the male. Valine was found to be present at 1.43 ± 0.019 g/100 g muscle in female compared to 1.37 ± 0.015 g/100 g muscle in male kudu MLD.

Leucine (female: 1.95 ± 0.023 g/100 g, male: 1.91 ± 0.014 g/100 g muscle) and lysine (female: 1.57 ± 0.040 g/100 g; male: 1.57 ± 0.037 g/100 g muscle) are the essential amino acids with the highest concentrations. In a study of the MLD of impala, leucine and lysine were also found to be the essential amino acids with the highest concentrations (Hoffman, Kritzinger, & Ferreira, 2005).

Table 4
Amino acid composition (g/100 g muscle) of *Longissimus dorsi et lumborum* muscle in female ($n = 10$) and male ($n = 8$) kudu

Amino acid	Female ($n = 10$)	Male ($n = 8$)	$Pr > \|t\|$
Essential			
Arginine	1.18 ± 0.012	1.16 ± 0.009	0.189
Histidine	0.93 ± 0.016	0.86 ± 0.012	0.003
Isoleucine	1.17 ± 0.016	1.13 ± 0.010	0.052
Leucine	1.95 ± 0.023	1.91 ± 0.014	0.119
Lysine	1.57 ± 0.040	1.57 ± 0.037	0.917
Methionine	0.61 ± 0.007	0.60 ± 0.004	0.290
Phenylalanine	0.75 ± 0.013	0.73 ± 0.007	0.214
Threonine	1.30 ± 0.020	1.27 ± 0.014	0.161
Valine	1.43 ± 0.019	1.37 ± 0.015	0.030
Non-essential			
Alanine	2.06 ± 0.025	1.98 ± 0.023	0.040
Aspartic acid	2.23 ± 0.031	2.15 ± 0.024	0.068
Cystine	0.13 ± 0.002	0.13 ± 0.002	0.277
Glutamine	3.14 ± 0.033	3.08 ± 0.030	0.219
Glycine	1.72 ± 0.028	1.65 ± 0.022	0.077
Proline	1.12 ± 0.012	1.10 ± 0.011	0.173
Serine	1.16 ± 0.016	1.13 ± 0.008	0.091
Tyrosine	0.62 ± 0.007	0.60 ± 0.006	0.105

3.5. Minerals

The mineral content of kudu meat compared with those of antelope (*Antilocapra americana*) and (*Bosephalus tragocamelus*), deer (*Odocoileus spp.*) and elk (*Cervus elaphus nelsoni*) are shown in Table 5. Potassium and sodium levels in both male and female kudu are considerably lower than the levels found in antelope, deer and elk (USDA, 1989). Variations in the mineral composition of meat can be caused by various factors, such as the concentration of minerals in the diet, hormones, age, gender, species and region (Doyle, 1980). Gender made no significant difference ($P < 0.05$) in the mineral composition of kudu MLD. This is consistent with the findings of Hoffman et al. (2005) for impala meat and Kroucamp (2004) for springbok meat, where no significant differences between genders were noted.

In kudu, MLD phosphorus was present in the highest concentration (female: 173 ± 2.71 mg/100 g; male: 172 ± 5.82 mg/100 g muscle), followed by potassium and sodium

Table 5
The mineral content (mg/100 g muscle) in female and male kudu, antelope, deer and elk

Mineral (mg/100 g muscle)	Kudu		Antelope[a]	Deer[a]	Elk[a]
	Female ($n = 10$)	Male ($n = 8$)			
Phosphorus	173 ± 2.71	172 ± 5.82	188	202	161
Potassium	119 ± 1.58	120 ± 2.44	353	318	312.0
Magnesium	24.3 ± 0.377	23.9 ± 0.673	27.0	23.0	23.0
Sodium	7.41 ± 0.120	7.59 ± 0.302	51.0	51.0	58.0
Calcium	4.62 ± 0.423	6.01 ± 2.29	3.0	5.0	4.0
Iron	2.79 ± 0.173	2.85 ± 0.230	3.19	3.4	2.76
Copper	0.01 ± 0.002	0.02 ± 0.004	0.18	0.25	0.12
Zinc	1.19 ± 0.090	1.37 ± 0.111	1.28	2.09	2.40
Manganese	0.04 ± 0.001	0.05 ± 0.007	0.02	0.04	0.012

[a] USDA (1989): pp. 8–17.

(Table 5). In springbok, MLD phosphorus was also found to be the most abundant mineral, followed by potassium and calcium (Kroucamp, 2004). In a study on ostrich meat, potassium was quantitatively the most important mineral, followed by phosphorus (Sales & Hayes, 1996).

4. Conclusion

The results from this study show that kudu meat can be regarded as a lean, healthy meat due to the low lipid content (≈1.5 g per 100 g meat) and high protein content (≈24 g per 100 g meat). However, no significant differences between the sexes were found in the physical characteristics or proximate composition. Only two of the longer-chained polyunsaturated fatty acids (C20:3*n*−6 and C20:5*n*−3) differed significantly between the females and males, with males having the higher concentrations. Kudu meat has a high concentration of PUFAs. The mean desirable fatty acid (stearic acid plus all unsaturated fatty acids) content of 83% is very high. The ratio of *n*−6 to *n*−3 PUFA's is balanced and well below the British Department of Health's recommended figure of four and this further promotes the health benefits of kudu meat. All essential amino acids are present in kudu meat. However, only histidine and valine contents differed significantly between the sexes. The most abundant mineral in kudu meat was phosphorus, followed by potassium.

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References

AOAC., (1997). *Official methods of analysis*. (16th ed.) Arlington, Virginia. Washington, DC. USA: Association of Official Analytical Chemists Inc.

Bender, A., (1992). *Meat and meat products in human nutrition in developing countries*. Food and nutrition paper 53. Food and agriculture organisation of the United Nations.

Berry, M. P. S. (1986). A comparison of different wildlife production enterprises in the Northern Cape Province, South Africa. *South African Journal of Wildlife Research, 16*, 124–128.

Bidlingmeyer, B. A., Cohen, S. A., & Tarvin, T. L. (1984). Rapid analysis of amino acids using pre-column derivatisation. *Journal of Chromatography, 336*, 93–104.

Byrne, C. E., Troy, D. J., & Buckley, D. J. (2000). Postmortem changes in muscle electrical properties of bovine *M. longissimus dorsi* and their relationship to meat quality attributes and pH fall. *Meat Science, 54*, 23–34.

Doyle, J. J. (1980). Genetic and non-genetic factors affecting the elemental composition of human and other animal tissues – a review. *Journal of Animal Science, 50*, 1173–1183.

Eloff, T. (2002). The economics of the game industry in South Africa. In H. Ebedes, W. Reilly, W.Van Hoven, B. Penshorn, (Eds.), *Sustainable conservation in practice* (pp. 78–86).

Eloff, T. (2005). Game sales statistics for 2004. *African Indaba e-Newsletter*, Vol. 3(2) 2005. http://www.africanindaba.co.za/Archive05/AfricanIndabaVol3-2.

Enser, M., Hallet, K. G., Hewett, B., Fursey, G. A. J., & Wood, J. D. (1996). Fatty acid content and composition of English beef, lamb and pork at retail. *Meat Science, 4*, 443–458.

Estes, R. (1991). *The behavior guide to African mammals*. Berkeley and Los Angeles, California: The University of California Press.

Giron, H.C. (1973). Dry ashing, Method 6.1.1. Atomic Absorption Newsletter, Vol. 12 (pp. 28).

Hoffman, L. C. (2000). Meat quality attributes of night-cropped impala (*Aepyceros melampus*). *South African Journal of Animal Science, 30*, 133–137.

Hoffman, L. C. (2003). Tourism and game meat – an opportunity we can't afford to miss? *South African Game and Hunting*, 23, November 2003.

Hoffman, L. C., & Bigalke, R. C. (1999). Utilising wild ungulates from southern Africa for meat production: potential research requirements for the new millennium. In: Congress of the wildlife management association of South Africa, George, South Africa.

Hoffman, L. C., Crafford, K., Muller, N., & Schutte, D. (2003). Perceptions and consumption of game meat by a group of tourists visiting South Africa. *South African Journal of Wildlife Research, 33*, 125–130.

Hoffman, L. C., Kritzinger, B., & Ferreira, A. V. (2005). The effects of region and gender on the fatty acid, amino acid, mineral, myoglobin and collagen contents of impala (*Aepyceros melampus*) meat. *Meat Science, 69*, 551–558.

Hoffman, L. C., & Wiklund, E. (2006). Game and venison – meat for the modern consumer. *Meat Science, 74*, 197–208.

Honikel, K. O. (1998). Reference methods for the assessment of physical characteristics of meat. *Meat Science, 49*, 447–457.

Huntley, B. J. (1971). Carcass composition of mature male blesbok and kudu. *South African Journal of Animal Science, 1*, 125–128.

Jansen Van Rensburg, D.M., (2001). Venison as health food. In *Proceedings of the 5th international wildlife ranching symposium*, Pretoria, March, 2001.

Kroucamp, M., (2004). Meat quality characteristics of the springbok (*Antidorcas marsupialis*). M.Sc in Agriculture Thesis, University of Stellenbosch, South Africa.

Lawrie, R. A. (1998). *Meat Science* (6th ed.). Cambridge, England: Woodhead Publishing Ltd. (pp. 258–269).

Lee, C. M., Trevino, B., & Chaiyawat, M. (1996). A simple and rapid solvent extraction method for determining total lipids in fish tissue. *Journal of the Association of Official Analytical Chemists, 79*, 487–492.

Olivier, E., & Van Zyl, A. (2002). Commercial game industry affected by new meat hygiene regulations. *South African Game and Hunting*, 24–25 December 2002.

Sales, J., & Hayes, J. P. (1996). Proximate, amino acid and mineral composition of ostrich meat. *Food Chemistry, 56*, 167–170.

Sayanova, O. V., & Napier, J. A. (2004). Eicosapentaenoic acid: biosynthetic routes and the potential for synthesis in transgenic plants. *Phytochemistry, 65*, 147–158.

Tichelaar, H. Y., Smuts, C. M., Van Stuiivenberg, M. E., Faber, M., & Benadé, A. J. S. (1998). The fatty acid composition of rural school children with helminth infections. *Asia Pacific Journal of Clinical Nutrition, 7*, 196–197.

USDA, (1989). Composition of foods: lamb, veal, and game products; raw, processed, prepared. Agricultural handbook. (pp. 8–17). http://www.nal.usda.gov/fnic/foodcomp/cgi-bin/list_nut_edit.pl.

Van Der Waal, C., & Dekker, B. (2000). Game ranching in the Northern Province of South Africa. *South African Journal of Wildlife Research, 30*, 151–156.

Walker, C. (1996). *Signs of the wild*. Cape Town, South Africa: Struik Publishers.

Wiklund, E., Pickova, J., Sampels, S., & Lundström, K. (2001). Fatty acid composition of *M. longissimus lumborum*, ultimate muscle pH values and carcass parameters in reindeer (*Rangifer tarandus tarandus* L.) grazed on natural pasture or fed a commercial feed mixture. *Meat Science, 58*, 293–298.

Wood, J. D., Richardson, R. I., Nute, G. R., Fisher, A. V., Campo, M. M., Kasapidou, E., et al. (2003). Effects of fatty acids on meat quality: a review. *Meat Science, 66*, 21–32.