A comparison between the effects of day and night cropping on greater kudu (*Tragelaphus strepsiceros*) meat quality

Louv C. Hoffman* & Liesel L. Laubscher

Department of Animal Sciences, University of Stellenbosch, Private Bag X1, Matieland, 7602, South Africa

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The greater kudu (*Tragelaphus strepsiceros*) has become a popular ungulate species for game meat production and the purpose of this study was to determine the effects of day and night cropping on its meat quality. Eight animals were cropped during the day and eight at night. Day-cropped animals had higher mean behavioural scores (perceived amount of *ante-mortem* stress experienced) and cortisol levels (behavioural score = 3.0 ± 0.641; cortisol = 68 ± 1.28 nmol/l) than night-cropped animals (behavioural score = 1.8 ± 0.955; cortisol = 14 ± 2.15 nmol/l). The muscle ultimate pH (pHu) values differed significantly between the two treatments (day-cropped animals = 5.40 ± 0.030; night-cropped = 5.48 ± 0.041). Significant differences were also found in drip loss (day-cropped = 2.76 ± 0.261%; night-cropped = 1.36 ± 0.361%) and in shear force between treatments (day-cropped = 3.45 ± 0.171; night-cropped = 4.06 ± 0.237 kg/1.27 cm diameter). No differences were found between the treatments for any of the colour ordinates, except L* values (day-cropped: 33.45 ± 0.435; night-cropped: 32.13 ± 0.601). The results of this study are inconclusive in that although day-cropped animals experienced more *ante-mortem* stress and, as a result produced meat with higher drip loss, they had a lower shear force and a paler colour, which are positive meat quality attributes associated with less stress.

**Key words:** kudu, cropping, meat quality, meat tenderness, meat colour, sustainable utilization.

**INTRODUCTION**

The greater kudu (*Tragelaphus strepsiceros*) is a popular species for game meat production and according to Patterson & Khosa (2005), greater kudu was the second most utilized species for game meat production (64 000 tons of total game meat per year) in South African between 2002 and 2004. Although the total amount of game meat exported in 2008 was lower (2233 tonnes: due to export restrictions), greater kudu accounted for 4.1% of the 85 537 animals cropped and contributed 12.5% to the weight of game meat exported. Thus, scientifically based information on the factors affecting its meat quality is required in order for it to compete with existing meat products. As noted by Skinner (1984), when producing game meat from wild ungulates the same criteria apply as those applying to meat production from domestic livestock; these include carcass yield, chemical composition and meat quality (Issanchou 1996). In the case of wild ungulates, good management practices that ensure acceptable meat quality are complicated by the inherently wild behaviour of the animals, such that slaughtering does not occur in a conventional manner (Renecker et al. 2001). In southern Africa, the plains game species are usually cropped commercially during either the day or at night with the use of vehicles, boma capture or helicopters (Hoffman & Wiklund 2006). All of these methods hold advantages and disadvantages and may be better suited to some species than to others, depending on the species’ behaviour. The two most popular cropping methods are shooting from vehicles during either the day or at night with many authors believing night cropping to be the least stressful method (Von La Chevallerie & Van Zyl 1971; Lewis et al. 1997; Veary 1991; Hoffman 2001; Kritzinger et al. 2002) although little research has been conducted on the differences between day and night cropping on different ungulate species.

The purpose of this investigation was to determine the effect of day and night cropping by a professional cropping team (as would be the case in the commercial production of game meat) on the meat quality of greater kudu, with particular emphasis on *ante-mortem* stress.

**METHODS**

**Animals**

Sixteen greater kudu were cropped for this study, eight during the day and eight at night.
Night cropping occurred according to the method described by Lewis et al. (1997) with animals being detected and temporarily immobilized with spotlights before being shot. Two vehicles were used and a single shooter per vehicle fired all the shots using either a .22–50 or .234 rifle, fitted with a telescopic sight and silencer and no animals were shot at distances exceeding 150 m. During the day, the same procedure was used as during the night cropping although animals were sighted and shot from the vehicles at distances ranging from 50 to 300 m. This was due to increased visibility during the day, allowing for head and neck shots at these distances as well.

Daytime ambient temperatures ranged between 12°C and 15°C while night-time ambient temperatures ranged between 2°C and 3°C. All the shots taken were either head- or neck shots, with the exception of three animals that were wounded either in the shoulder or neck. All wounded animals were recovered and killed within a few minutes after being shot. A behavioural score relating to the perceived amount of ante-mortem stress experienced by each animal was allocated to each animal as per Table 1.

Cropping

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Cropping occurred over a two-day period. All the night-cropped greater kudu were shot on the first evening and two of the day-cropped greater kudu shot during the first day. These animals were all shot at Neudamm Agricultural College, 30 km south of Windhoek. These carcasses remained on the vehicles for 2–4 hours before being loaded into the cooling truck. The remaining six greater kudu were shot on the second day at Vredenheim Farm in the Khomas Hochland, 40 km east of Windhoek. All the carcasses shot at Neudamm were cooled with their skins intact in a cooling truck at 0°C to 5°C and then transported after 48 hours to Farmer’s Meat Market in Windhoek, where they were skinned, weighed again and the trachea (red pluck), which was separately weighed was removed for health inspection. The six greater kudu shot on the second farm remained on the hunting vehicle until being transported to Farmer’s Meat Market that evening, where they were placed in a cooling truck at 0°C to 5°C. Twenty-four hours after being shot, these carcasses were skinned, the organs and red pluck removed and all components weighed.

Ultimate pH measurements were taken at 24 hours post-mortem. Due to unforeseen circumstances, only pH measurements at 48 hours post-mortem could be taken on the six animals shot at Vredenheim and as is was assumed that ultimate pH had already been reached by 24 hours post-mortem and that slight pH changes after that would be negligible, these values were taken as being the same as if measured at 24 hours post-mortem.

Blood samples

Blood samples were collected during exsanguination, kept on ice for approximately 3–4 hours and then centrifuged for 10 minutes, after which the serum was poured into clean tubes and frozen. The frozen serum samples were sent to the Pathcare (Drs Dietrich, Voight, Mia Partners) veterinary laboratories (Practice No.: 5200539) Goodwood, Cape Town, where they were analysed for serum cortisol levels (nmol/l), using an Access Cortisol assay.

Physical analysis

Two sub-samples, 1.5 cm to 2.0 cm thick were taken from the M. longissimus dorsi of each carcass after 48 hours post-mortem and used to determine drip loss, cooking loss, Warner-Bratzler shear force values and to record the colour measurements according to the methods described by Honikel.
The colour was measured in terms of L*, a* and b* values with L* indicating lightness or reflectance, a* indicating the red-green range and b* indicating the blue-yellow range. These values were then also used to calculate the hue angles (h°) and chroma values (C°), using the following equations:

Hue angle: \( h° = \tan^{-1}\left(\frac{b°}{a°}\right) \)

Chroma value: \( C° = \left[\left(a°\right)^2 + \left(b°\right)^2\right]^{1/2} \).

Statistical analysis
Both pH measurements at 24 (first 12 animals) and 48 hours (last six day-cropped animals) post-mortem were taken as ultimate pH (pHu) and compared as such. Analysis of variance (ANOVA) was used to test for differences in meat quality, as well as pHu with treatment (shooting method) as main effect, using SAS version 8.2 (SAS 2002). Pearson's correlation coefficients were calculated where applicable. The differences between cropping methods were, where appropriate, tested separately by means of the null hypothesis (\( H₀ \)) with \( H₀° = \mu₁ \) and the alternate hypothesis (\( H₁° \)) being \( H₁° \neq \mu₂ \). Differences within the main effects were accepted as being significant if the probability of rejection of \( H₀ \) was less than 5% (\( P < 0.05 \)).

RESULTS AND DISCUSSION

Behavioural score
There was a difference (\( P = 0.038 \)) in behavioural scores between the two cropping methods with day-cropped animals having higher mean behavioural scores (3 ± 0.641) than night-cropped animals (1.8 ± 0.955). This indicated that the day-cropped greater kudu may have experienced more stress during the cropping operation. The behavioural scores were strongly correlated with the blood cortisol levels (\( P < 0.0001; r = 0.823 \)), indicating that the subjective behavioural score was a good indication of the stress experienced by the animals.

Cortisol
Differences (\( P = 0.004 \)) were found in serum cortisol levels between the day- and night-cropped greater kudu with day-cropped greater kudu having higher cortisol levels (68 ± 1.28 and 14 ± 2.15 nmol/l, respectively), thus indicating that the day-cropped animals experienced a greater amount of ante-mortem stress. It must be noted, however, that the cortisol levels of both the day- and night-cropped animals are within the mean cortisol ranges that were reported for other African ungulates such as impala (19.4–148 nmol/l) and roan antelope (Hyloproagus equinus) (23.0–135.0) by Hattingh (1988).

pH
The major influence that pre-slaughter stress has on meat quality is its effect on muscle glycogen content which can cause a higher than normal ultimate pH (pHu) or rate of pH decline. pHu is often used as an indicator of ante-mortem stress, especially in wild and domestic ruminants where dark, firm and dry (DFD) meat is a common problem associated with a higher than normal pHu caused by excessive chronic pre-slaughter stress (Wiklund et al. 2001). Alternatively, a lower than normal pHu as a result of acute pre-slaughter stress may result in a loss in water-holding capacity of the meat and a paler appearance of the meat (Swatland 2004). Knox et al. (1991) found that the physical exertion and stress associated with live capture in impala caused a significant increase in the plasma and muscle lactate concentration which, if pH had been measured post-mortem, would result in a higher than normal pHu owing to a depletion of pre-slaughter glycogen stores. In the current investigation, a difference (\( P = 0.030 \)) was found in the pHu between the two treatments, so that night-cropped animals had a higher mean pHu value (5.48 ± 0.041) than day-cropped animals (5.40 ± 0.030). The differences in pHu may be attributable to the differences in serum cortisol levels in that the higher serum cortisol levels of the day-cropped animals caused the mobilization of the animals' glycogen stores shortly before death which resulted in an increased rate and extent of lactic acid formation and muscle acidification post-mortem. The differences in pHu were also found to be correlated to some of the meat quality parameters measured (see later) in this study and may thus partly explain differences found in these parameters. The findings of this study are in contrast to those of Veary (1991) and Kritzinger et al. (2002), who both found that pHu was consistently higher in day-cropped impala and springbok respectively, compared to that of night-cropped animals. However, the levels of ante-mortem stress in these two reports were higher than that experienced in the present study; for example, in the study of Kritzinger et al. (2002) an inexperienced shooter was used and the animals were also shot on foot.
Water-holding capacity and tenderness

Drip loss and cooking loss are both functions of the water-holding capacity (WHC) of meat. Ante-mortem stress can affect the WHC of meat by affecting the pH of the meat since pH affects the affinity of meat to bind and hold water. When a high rate of pH decline occurs because of acute ante-mortem stress, low pH values are usually reached while muscle temperatures are high so that denaturation of the muscle proteins occurs that causes a decrease in their ability to bind water and thus decreases their WHC. In addition, lower pH values result in reduced net muscle protein charge (movement towards isoelectric point), also causing reduced water-holding capacity (Swatland 2004). On the other hand, chronic stress, particularly when experienced over a long period, can lead to a higher than normal pHu that increases the WHC of the meat such that little or no exudate is formed.

In the current investigation there was a difference (P = 0.012) in drip loss between the treatments such that day-cropped animals produced higher drip loss values than night-cropped animals (Table 2). This is consistent with the finding that day-cropped animals may have experienced more ante-mortem stress, which may have caused a more rapid pH decline whilst the carcass temperatures were still relatively high causing a denaturation of muscle proteins and a loss of WHC. The results from this study are in agreement with those of Kritzinger et al. (2002), who found that day-cropped impala had higher mean drip loss values (4.15 ± 2.339%) than night-cropped impala (2.93 ± 1.597%), although these values are much higher than those reported in the current investigation. A negative correlation (Table 3) was found between the drip loss values and pHu in the current investigation, indicating that a lower pHu would result in a lower WHC and thus higher drip loss values. Hoffman et al. (2007) found similar results and reported that pHu was correlated (P < 0.01; r = −0.26) to drip loss in springbok. No difference was found in cooking loss between the two treatments.

Tenderness is often considered to be a decisive factor in determining meat quality by consumers (Koohmaraie et al. 2003) and many authors have found it to be closely related to the pH of meat (Bouton et al. 1971). In the current investigation, a positive correlation was found between pHu and shear force (Table 3), although this correlation was not strong. This result is similar to previous research (Purchas 1990), which reported that an increase in meat toughness is accompanied by an increase in pHu from about 5.5 to 6.2, partially as a result of decreased sarcomere length at this pH region. Since the pHu values of the greater kudu ranged from 5.30 to 5.57, it may explain why the correlation is not strong. Hoffman et al. (2007) also found similar results, with pHu being positively correlated to shear force (P < 0.01; r = 0.25) in springbok.

Differences (P = 0.003) were found between treatments for shear force, with night-cropped animals producing tougher meat than day-cropped animals (Table 2). This is in contrast to the findings of Kritzinger et al. (2002) who found that day-cropped impala produced tougher meat than night-cropped impala. The correlation between pHu and tenderness (Table 3) may partly explain the difference between treatments, since night-

### Table 2. Mean values of the physical meat quality parameters (LSMean ± S.E.) as measured in the M. longissimus dorsi of day- and night-cropped greater kudu.

| Parameter                      | Cropping technique | P < |t| |
|-------------------------------|--------------------|-----|---|
| Drip loss (%)                 | Day                | 2.76 ± 0.261 | Night | 1.36 ± 0.361 | 0.012 |
| Cooking loss (%)              | Day                | 34.14 ± 1.337 | Night | 34.35 ± 1.849 | 0.880 |
| Shear force (kg/1.27 cm diameter) | Day                | 3.45 ± 0.171 | Night | 4.06 ± 0.237 | 0.003 |

### Table 3. Pearson linear correlation coefficients (r) between pHu and the physical attributes of the day- and night-cropped greater kudu.

| Characteristic              | r     | P < |t| |
|----------------------------|-------|-----|---|
| Cooking loss               | 0.156 | 0.563 |
| Drip loss                  | −0.779 | 0.0004 |
| Shear force (kg/1.27 cm diameter) | 0.506 | 0.0003 |
| L*                         | −0.236 | 0.379 |
| a*                         | −0.073 | 0.788 |
| b*                         | 0.155 | 0.568 |
| Chroma                     | 0.208 | 0.440 |
| Hue                        | 0.029 | 0.914 |
Cropped animals had higher pHu values than day-cropped animals. Furthermore, the differences in ambient temperatures between day and night (daytime ambient temperatures ranged between 12°C and 15°C, while nighttime ambient temperatures ranged between 2°C and 3°C), and the fact that six of the animals cropped during the day were not loaded into the cooling truck until at least six hours post-mortem may have resulted in night-cropped carcasses cooling at a much faster rate and, since temperature is known to affect tenderness, this increased cooling rate may account for some of the differences in shear force between the treatments. A fast decrease in temperature while the pH of the muscle is still relatively high is known to decrease tenderness as the result of a phenomenon known as cold shortening (Pearson & Young 1989).

**Colour**

Meat colour is an important selection criterion for consumers (Ouali et al. 2006) and can often give an indication of the effect of pre-slaughter treatment on the meat quality. Although game meat is generally accepted as being a dark red colour, exceptionally dark meat may be indicative of DFD which is caused by chronic ante-mortem stress. The only difference for colour ordinates between treatments was for L* values (P = 0.015), with day-cropped animals producing paler meat than night-cropped animals (Table 4). Kritzinger et al. (2002), on the other hand, found no differences in any of the colour ordinates between day- and night-cropped impala. Differences in L* may be attributable to the differences in pHu, since, according to Swatland (2004), the myofilament lattice shrinks as the pH decreases, causing an increase in the myofibrillar refractive index and an increase in the light scattering of the meat. This would cause the meat to be paler.

Ultimate pH values indicated differences between the day- and night-cropped animals, with night-cropped animals having a higher mean pHu than day-cropped animals; neither cropping methods produced pH values high enough or low enough to be considered detrimental to the meat quality, even though the serum cortisol levels and the subjective behavioural scores indicated that day-cropped animals experienced more ante-mortem stress than night-cropped animals. Although the meat quality values were not extreme enough for it to be considered as PSE, it is likely that the stress experienced by the day-cropped animals in the current investigation had an effect on the pH of the muscle post-mortem and that this, coupled with the differences in rates of temperature decline, was enough to cause differences in the meat quality between the treatments. As a result, day-cropped animals produced meat that had a higher mean drip loss percentage and lower mean shear force, as well as being paler in colour. Although differences in drip loss, shear force and paleness of the meat, does suggest that night cropping caused less ante-mortem stress than day cropping it is argued that the differences are slight and would not negate the advantages of day cropping. However, due to the limited sample size as well as the fact that the sampling took place at a single time period, it is suggested that a more detailed investigation be conducted. Some of the advantages of day cropping include: better off-take rate as more animals are visible at longer distances—an experienced shooter has no difficulty in shooting an animal in the head at distances over 200 m; the better visibility in the day-time allows for a more rapid loading of carcasses—not only because the carcasses are more visible but also the route to the carcasses is more visible and it is easier to avoid holes, tree stumps, etc.; selective cropping is possible because of the visibility of the animals/herd; a longer cropping period is thus possible as night cropping is restricted to dark moonless

| Colour ordinates | Cropping method | P < | t |
|------------------|----------------|-----|--
| L* 33.45 ± 0.435 | 32.13 ± 0.601 | 0.015 |
| a* 15.46 ± 0.597 | 14.50 ± 0.826 | 0.109 |
| b* 10.73 ± 0.519 | 10.61 ± 0.718 | 0.836 |
| C* 18.90 ± 0.655 | 18.02 ± 0.906 | 0.254 |
| H_ab 34.58 ± 1.439 | 36.32 ± 1.989 | 0.207 |

| Table 4. LSMeans (± S.E.) of L*, a*, b*, hue-angle (H_ab) and chroma values (C*) of greater kudu M. longissimus dorsi (LD) muscle for both cropping methods. |
nights. However, the higher day time ambient temperatures and the presence of flies would require that the carcasses be processed and placed into a cooler as soon as possible.

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