A comparison between the effects of two cropping methods on the meat quality of impala (*Aepyceros melampus*)

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Abstract

Impala (*Aepyceros melampus*) constitute one of the most commercially important species in game farming in South Africa. The purpose of this study was to compare the effects of day and night cropping on the meat quality characteristics of impala. Emphasis was placed on the influence of the cropping method on muscle pH_{45} (45 minutes post mortem), pH_u (ultimate pH), pH decline, and the related influence on drip loss, cooking loss, toughness and colour of the meat in the *M. longissimus lumborum*. Measurements taken from 16 animals cropped at night were compared to those taken from 24 animals cropped in daytime. A mean pH_{45} of 6.67 ± 0.11 was recorded for the night cropped animals compared to a mean pH_{45} of 6.55 ± 0.23 for the day cropped animals. A mean pH_u of 5.39 ± 0.08 for animals cropped at night was recorded compared to a mean pH_u of 5.45 ± 0.11 for the animals cropped in the day. Regression analysis showed the rate of pH decline to be slower in the night cropped animals compared to those cropped in the day. This persisted when the pH values were adjusted to correct for ambient temperature. The cooling rate of the *M. longissimus lumborum* was twice as fast in the night cropped group. Shear force values and drip losses respectively, for the night-cropped animals were 19.11 ± 5.68 g/mm^2 and 2.93 ± 1.59%, whereas for the day cropped animals the values were 23.42 ± 8.13 g/mm^2 and 4.15 ± 2.34%. The results of this study indicate that night-time cropping does have a beneficial effect on certain meat quality parameters.

Keywords: Meat quality**,** impala, cropping methods
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Introduction

Game ranching is recognised by the South African agriculture and conservation authorities as a *bona fide* form of agricultural land use (Eloff, 2002). To date there are more than 9000 fenced commercial game farms in the country. A further 15000 farms have game on them that are economically utilised in some form or another (Van Zyl, 2000). The game industry increased by an average of 5.6% per annum between 1993 and 2000 in terms of the size of exempted game ranches (Eloff, 2002) and excluding Provincial and National Parks, these game farms comprise 12.5% of South Africa's agricultural land. Van der Waal & Dekker (2000) calculated that the game ranches in the Limpopo Province alone covered a total surface area of 3.6 million ha in August of 1998, which represents 26% of the total area of the province. According to these authors, this is part of the generally recognized trend away from conventional livestock production to game production. The reasons for this, when compared to a traditional domestic stock farming operation, are that there is a perceived greater financial return from a game farming operation, it is aesthetically pleasing and ostensibly more environmentally friendly.

The potential of wild ungulates for meat production is something that has been realized for some time now (Ledger, 1963; Ledger *et al.*, 1967; Skinner, 1984). The impala's wide distribution in southern Africa and its relative abundance make it well suited to continuous cropping for game meat production (Bourgarel *et al.*, 2002). In South Africa, the impala is the single most important species in the Lowveld and Bushveld areas in terms of its population numbers (Hoffman, 2000a). A recent study by Eloff (2002) showed that impala are the most popular game species at game auctions, making up almost a third of the total number of animals sold. This is the case because of their relative abundance when compared to other species and the fact that new game farmers who wish to establish game populations on their farms are able to buy them without stretching their financial resources. They tend to be seen as the "bread and butter" of a game farming operation because of their rapid population growth rates (Fairall, 1985) and so they are easily traded. The smaller and newer game farms do not usually have resident predator populations because of restrictive farm sizes and certain financial implications. Without this natural form of population control it soon becomes

necessary to crop animals in order to prevent overgrazing and destructive interspecies competition. In the light of this growing industry the development of efficient cropping methods for game has become an aspect that requires urgent attention.

Culling methodologies such as the two used in this study are generally accepted practice in South Africa. This is because of the fact that game farming for meat production has not yet reached the same level of sophistication as it has in other parts of the world, like New Zealand and Europe. There, deer farming has become a finely honed industry where partially tame animals are kept in paddocks and slaughtered in commercial abattoirs (Stevenson *et al.*, 1992; Aidoo & Haworth, 1995; Bradshaw & Bateson, 2000; Wiklund *et al.*, 2001; Pollard *et al*., 2002). In South Africa, because of the variability of size and area of the farming terrain, and the long distances between production centres and markets, it is necessary to implement other practical methods to crop game.

Studies on the effects of night shooting on the meat quality of southern African game have been conducted in the past by Hoffman (2000b) and Hoffman & Ferreira (2000). There has also been some work done on the effects of shooting on the meat quality of wild ungulates by Veary (1991) and Von la Chevallerie & Van Zyl (1971), but apart from that very little data could be found on the subject. This study was conducted to determine the effects of day- and nighttime cropping on selected meat quality parameters of impala, since there is no such information available. To our knowledge, this is the first study that makes a qualitative comparison between animals harvested at night and those harvested in the day.

Materials and Methods

The cropping of impala herds took place at the Mara Research Station (23° 05' S and 29° 25' E; 961 m.a.s.l.) in the Limpopo Province, South Africa. The study area is located 50 km west of Makhado (Louis Trichardt), just south of the Soutpansberg mountain range. The Mara Research Station is situated in the Arid Sweet Bushveld (Acocks, 1988) and is 11 000 ha in extent. The vegetation found there includes the woody species *Acacia tortilis, Commiphora pyracanthoides, Boscia albitrunca and Grewia* spp. The grass species found include *Eragrostis rigidior, Panicum maximum, Urochloa mosambicensis* and *Digitaria eriantha.* The mean annual rainfall is 452 mm, of which approximately 80% occurs from November to March. The mean daily maximum temperature ranges from 22.6 °C in June to 30.4 °C in January (Dekker *et al.*, 2001). The type of work done there is primarily concerned with research on extensive cattle production. Impala occur naturally in the area and as they are in competition with the cattle for grazing, they are subject to yearly population reductions.

For this study, two cropping methods were used, namely night-time (or spotlight cropping) and daytime. During the night-time (spotlight cropping) operation 16 animals of random age and sex were harvested. Two marksmen (armed with .30 calibre high velocity rifles) and an observer (operating a 1 million-candela spotlight) went out on moonless evenings in a pick-up truck (Lewis *et al.*, 1997). Animals were sighted either directly or by the reflection of light from their retinas. Targeted animals were shot high in the neck so that the bullet destroyed all arterial blood supply to the head as well as the spinal connection to the body. This rendered instantaneous insensibility and resulted in almost no wastage of meat (Von la Chevallerie & Van Zyl, 1971). Ambient temperatures varied between 2-11 °C.

During the daytime operation, 24 animals of random age and sex were harvested. The animals were hunted on foot and high neck shots were once again used. Each marksman went out alone using the same rifle and ammunition (.30 calibre) as used during the nighttime operation. Ambient temperatures varied between 19-27 °C.

Following the shooting, the dead animals were immediately exsanguinated by cutting the throat with a sharp knife. pH (pH_{45}) and temperature ($temp_{45}$) readings were taken in the *M. longissimus lumborum* using a calibrated (standard buffers at pH 4.0 and pH 7.0) Crison 506 portable pH meter (Hoffman, 2000b). The animals were then transported to the abattoir where they were skinned, eviscerated and the carcasses cleaned according to standard South African and Zimbabwean practices (Hoffman, 2000b). The carcasses were then suspended by their Achilles tendons in a cooler set at 4 °C. pH profiles were taken from five animals selected randomly from those shot in the day and 10 randomly selected animals from those cropped at night, by measuring the pH and temperature of the carcasses every two hours for the first 12 h, and then every four hours for the following 12 h post mortem. The pH_u readings were taken from all of the carcasses 24 h post mortem.

Loin samples for proximate and meat quality analyses were taken from the carcasses 36 h after cropping. The samples were removed from the *M. longissimus lumborum* between the 1st and 4th lumbar vertebrae. Steaks (15 mm in thickness and weighing *ca*. 70 g) were cut perpendicular to the longitudinal axis of the muscle on the caudal side of the sample. These were used to determine the drip loss and cooking loss according to the methods set out by Honikel (1998). Cooking loss was determined by placing the weighed samples, sealed in polythene bags, into a water bath set at 80 °C for 1 h. Thereafter the samples were cooled under running water to 25 °C. They were then removed from the bags, blotted dry with paper towelling and weighed. The cooking loss was calculated using the amount of fluid lost during cooking and was expressed as a percentage of the uncooked sample.

For the Warner Bratzler shear force test, five 12.7 mm diameter samples were cut randomly from the cooked block of meat. Care was taken to ensure that no visible connective tissue was included in the cut section. The samples were cut perpendicular to the longitudinal axis of the muscle fibre so that the influence of the myofibrillar proteins on the shear force could be measured (Voisey, 1976). An average maximum shear force value was calculated (from five repetitions) based on the shear force (g/mm^2) required to shear the 12.7 mm diameter cylindrical core of cooked meat perpendicular to the grain, at a crosshead speed of 228 mm/min.

For the colour measurement of the meat, freshly cut steaks were allowed to bloom for 20 minutes where-after the colour was measured three times, at random positions on the steak surface (Stevenson *et al.*, 1989) using a Color-guide 45°/0° colorimeter (BYK-Gardener, USA). The colour was expressed in terms of L*, a* and b* values (Commission International de L' Eclairage, 1976), with L* indicating brightness or reflectance, a* the red-green range and b* the blue-yellow range. The hue angles (h_{ab}) and chroma values (C*) were calculated for the samples using the following equations (Commission International de L' Eclairage, 1976):

Hue angle: $H_{ab} = \tan^{-1}(b^*/a^*)$

Chroma value: $C^* = [(a^*)^2 + (b^*)^2]^{1/2}$

Analyses of variance were performed on all the variables measured within treatments using the software package Statistical Analysis System (SAS, 1989). No significant age or sex differences were found so the data were pooled for further analysis. Standard Student t-tests were then conducted with the time of cropping as the main effect. The non-linear regression procedure (Proc NLIN) of SAS (1989) was used to fit exponential decay models to the rate of pH decline and the rate of temperature decline for both the day and night cropped groups. The model used was in the form of:

$$y = a + b\, e^{(-ct)}$$

where: y is the dependent variable (pH or temperature) and t is the time (h). The a, b, and c values from the above mentioned regression model were then analysed using the t-test procedure of SAS (1989) to test for differences between the time of cropping.

As a result of the fact that there were differences found in the rate of muscle temperature decrease between the day and night treatments, the pH readings were standardized at 4 °C using the formula of Bruce *et al.* (2001):

$$pH_{adjusted\ at\ t} = \text{measured } pH_t + \{ (T_t - T_{adjusted}) * 0.01 \}$$

where: pH_t is the actual pH measured at time = t, T_t is the muscle temperature at time = t and $T_{adjusted}$ is the muscle temperature (4 °C) to which the data is being adjusted. The $pH_{adjusted}$ was then re-analysed as explained above using Proc NLIN (SAS, 1989).

Results and Discussion

Night cropping is perceived to be one of the most efficient ways of minimising stress on animals during cropping operations (Lewis *et al.,* 1997). It is of prime importance that cropping operations take place as humanely as possible, so it is necessary to utilise a strategy that best suits the individual circumstances on a particular farm. Tinley (1972) and more recently Veary (1991) reviewed the methods used for cropping and the technique that is most often used, is to shoot at night from a vehicle using spotlights. The impalas' alert and investigative posture that they adopt when caught in the spotlight makes them particularly well suited to night cropping (Lewis *et al.,* 1997). This is in contrast to an animal like the kudu (*Tragelaphus strepsiceros*) that tends to look away from the spotlight and take flight.

During the entire cropping operation only one loss occurred: that of an animal that was wounded during the night and never recovered. As a percentage of the total number of animals harvested, this loss makes up less than 2.5%. According to Lewis *et al*. (1997) this is well within the expected losses of ≤8% for a cropping operation. All the animals were shot high in the neck and died instantly. There was no wastage of any of the meat owing to the positioning of the shots (Von la Chevallerie & Van Zyl, 1971). Contrary to a study conducted by Hoffman (2000a), statistical analysis of these data did not show any significant sex differences. The sample sizes used for this study were larger than those sampled by Hoffman (2000a) and the age and sex of animals were randomised.

According to Bruce *et al*. (2001), the pH decline of muscle in a carcass deviates from a linear function. This is because when the muscle enters rigor, hydrogen ion production decreases as the rate of anaerobic glycolysis and myosin ATPase activity decrease during muscle cooling. Bendall & Davey (1957) found that post mortem pH decline is also slowed by the buffering effect of ammonium generated by the deamination of adenosine monophosphate (AMP). Therefore, because of this slowing in the rate of pH decline, it is best represented by an exponential decay curve (Bruce *et al*., 2001).

O'Halloran *et al.* (1997) noted that the rate of pH decline influences the toughness of meat particularly if the meat is susceptible to shortening. They went on to show that a slow pH decline increases the shear force value. However, work published by Marsh *et al.* (1987) showed that a slow rate of post mortem glycolysis produced tender meat. The results of this study are in agreement with the latter. The animals cropped at night showed a slower pH decline than those shot in the day (Table 1, Figure 1), but their shear force values are significantly lower ($P < 0.05$) (Table 2). According to the findings of Marsh *et al.* (1981) moderate rates of pH decline produce tender loin steaks and they cautioned that rapid pH decline would produce tough meat.

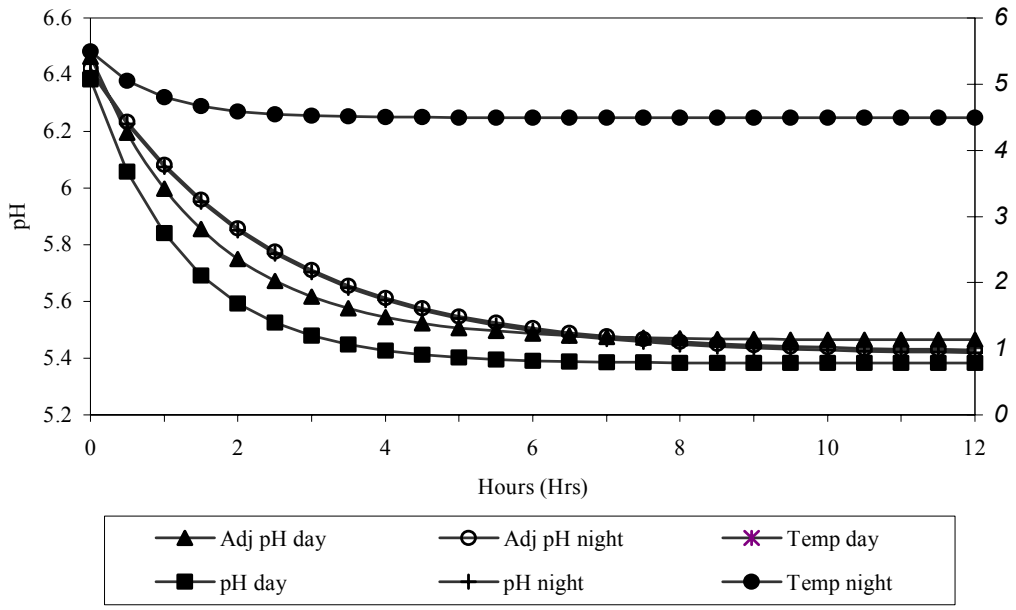

Figure 1 Mean *M. longissimus lumborum* temperature and pH profiles for day (n = 5) and night (n = 10) cropped impala at Mara

Non-linear regression analysis of the decrease in temperature of impala carcasses suggests that the temperature decrease for both treatments can be accurately described by an exponential decay model (Day: a = 8.03, b = 31.66, c = -0.15; Night: a = 4.49, b = 45.33, c = -0.31). The temperature drop of the night cropped group fell twice as fast as that of the day cropped group, thus indicating rapid cooling in the night cropped muscles (Figure 1).

Post mortem muscle that undergoes rapid anaerobic glycolysis usually reaches its ultimate pH while the temperatures are still high (≈ 20 °C) and might sometimes even show an increase in the apparent muscle pH as it cools (Bruce *et al*., 2001). Owing to the differences between the prevailing day and night ambient

temperatures, it was necessary to adjust the temperatures for both treatments to a standard 4 °C. This was done to remove the variation brought about by the effect of ambient temperature on the pH declines.

Table 1 The calculated constants (LSMean ± s.e.) for the exponential equations fitted to the pH decline under actual temperature conditions and under adjusted standard temperature (4 °C) for day (n = 5) and night (n = 10) cropped impala

$y = a + be^{-ct}$ constants	T	Normal pH decline	P < |t|	pH decline adjusted to std temp	P < |t|
a	D	5.38 ± 0.006	< 0.01	5.46 ± 0.006	< 0.01
	N	5.41 ± 0.004		5.42 ± 0.004	
b	D	2.93 ± 0.124	< 0.01	2.90 ± 0.086	< 0.01
	N	2.14 ± 0.083		2.47 ± 0.057	
c	D	-0.72 ± 0.040	< 0.01	-0.58 ± 0.027	< 0.01
	N	-0.53 ± 0.026		-0.45 ± 0.018	

T (Time) = D (Day) or N (Night)

The pH decline under the prevailing ambient temperatures in the day and night differed significantly, with the day cropped group having a more rapid rate of pH decline. The analysis was repeated after the temperature was adjusted to a standard 4 °C for both treatments (Figure 1, Table 1). The difference in pH between day and night cropping persisted with the standardised temperature and is likely as a result of the difference in ante mortem conditions experienced by the animals prior to death between the day and night treatments. It is likely that the difference arose as a result of the heightened stress level of the day cropped animals because of their awareness of the hunters. Another influence could be the heightened level of physical activity during the day, particularly during the rut, which would cause the glycolytic enzyme activity to remain high for a longer period, resulting in a more rapid pH decline. The relative unawareness of the animals of the croppers (and thus unstressed state) during night cropping would result in a lowered glycolytic enzyme activity and a slower rate of pH decline.

The pH_{45} of the animals cropped at night was significantly higher than those shot in the day ($P < 0.05$; Table 2). However, the pH_u of the day cropped animals was higher than those of the group harvested at night ($P < 0.05$). The fact that the day-cropped pH_{45} (6.55 ± 0.24) was lower than those of the night cropped animals (6.67 ± 0.11) may be attributed to the daytime activities of the animals. The study took place during May and June, and coincided with the impala rutting, or mating period (Fairall, 1985). This period is characterised by heightened physical activity for both sexes associated with mating behaviour (such as fighting, mounting, oestrus and gestation) and such activity necessitates the mobilisation of additional muscle glycogen (both aerobically and anaerobically, depending on the intensity of the activity).

Table 2 Mean pH values and physical meat quality parameters (LSMean ± s.e.) for the day (n = 24) and night (n = 16) cropped impala at Mara

	Day cropped	Night cropped	P < |t|
Mean pH_{45}	6.55 ± 0.235	6.67 ± 0.111	0.05
Mean pH_u	5.45 ± 0.108	5.39 ± 0.081	0.05
Drip loss (%)	4.15 ± 2.339	2.93 ± 1.597	0.05
Cooking loss (%)	32.87 ± 4.101	32.99 ± 5.109	0.90
Warner Bratzler shear force (g/mm^2)	23.42 ± 8.128	19.11 ± 5.675	0.05

A second aspect that would most certainly constitute a stress factor to the day-cropped animals is their awareness of the hunter. Lacourt & Tarrant (1985) mimicked the effect of this type of stress by administering exogenous doses of adrenaline to young bulls. Among the physiological responses that they reported, was a decline in the muscle glycogen content of such animals. This is in keeping with similar findings by Pollard *et al*. (2002) for red deer (*Cervus elaphus*). Muscle glycogen is the main metabolic substrate that is responsible for the formation of lactic acid, and thus normal post mortem pH decline of

muscle (Immonen *et al.*, 2000). The depletion of glycogen by one or other chronic form of stress before death will result in less lactic acid being formed and consequently the meat will not acidify properly and the pH_u will remain high (Viljoen *et al.*, 2002). The relationship between elevated pH_u and physical activity or chronic stress in deer has been observed in several studies (MacDougall *et al.*, 1979; Kay *et al.*, 1981; Smith & Dobson, 1990). Knox *et al.* (1991) found that the stress and exertion associated with the live capture of impala significantly raised the plasma lactate concentrations in the blood and muscles. They attributed this to the heightened muscular activity during the capture, which resulted in anaerobic glycolysis and the subsequent accumulation of lactic acid in the muscle tissue and blood. Hattingh *et al.* (1988) have reported similar findings. Increases in lactic acid concentrations in the tissue have been reported by Gericke *et al.* (1978) for springbok (*Antidorcas marsupialis*), Hofmeyer *et al.* (1973) for zebra (*Equus burchelli*) and by Harthoorn (1975) for eland (*Taurotragus oryx*) and tsessebe (*Damaliscus lunatus*). Ruminant animals usually have a lower blood glucose concentration than non-ruminant animals (Schaefer *et al.*, 1997) and this contributes to a lower muscle glycogen content as well as a slower rate of glycogen repletion. However, at night, glycogen stores are replenished causing the muscle pH_{45} to be slightly higher (McVeigh & Tarrant, 1982). It is therefore probable that the pH_u of the night-cropped animals is lower because of the greater amount of muscle glycogen available for post mortem glycolysis. The amount of muscle glycogen available for post mortem glycolysis, together with the temperature regime, also affects the rate of pH decline.

An important aspect of meat quality that ties in with the ultimate pH is the water binding capacity of the meat. The point of minimum water binding capacity is the iso-electric point, which is pH 5.4 – 5.5. Post mortem glycolysis usually reduces the ultimate pH of meat to around 5.4 – 5.5, so some moisture loss due to loss of water binding capacity is inevitable. A large proportion of the water present in muscle is found in the myofibrils between the actin and myosin filaments (Lawrie, 1998). Roughly 5% of it is bound to the hydrophilic groups on these proteins (Hamm, 1966). The higher the ultimate pH, the less water will be released by the tissue. Offer & Knight (1988) showed that drip loss is formed primarily from the extracellular space and that the latter increases with decreasing pH. Guignot *et al.* (1993) confirmed this in veal muscle. The night-cropped animals had a higher mean pH_u and lower average drip-loss compared to the day-cropped animals ($P < 0.05$; Table 2). Numerous other reports have noted the association between decreased water holding capacity and increased pH_u (Dransfield *et al.,* 1981; Purchas, 1990). The higher pH_u of the day-cropped animals is conducive to lowered water binding capacity and therefore a greater percentage of drip-loss. In a study conducted by Hoffman (2000b), drip loss values of 2.61 ± 1.24% and cooking loss values of 23.98 ± 1.41% were reported for impala cropped at night in central Zimbabwe. The drip loss reported by this author is very similar to the drip loss for the night cropped group of the present study.

The amount of cooking loss did not differ significantly between the day and night cropped groups (Table 2). The Warner-Bratzler shear force tests showed that the meat from the night cropped group was significantly more tender than that of the day cropped group ($P < 0.05$). Devine *et al.* (1993) found the same trend towards decreasing tenderness with increasing pH_u in lambs. A higher pH_u can lead to the association of the actin and myosin filaments of the day-cropped animals leading to shortening and decreased tenderness (Ouali, 1990).

The colour of meat is of critical importance in creating an impression when meat is viewed (Clydesdale, 1991; Gasperlin *et al.,* 2000) and is used as an indicator of flavour, tenderness and freshness (Naumann *et al.,* 1957). No significant differences between the two treatments were noted in so far as the colour of the meat was concerned (Table 3). The hue angle (h_{ab}) and chroma (C*) values were also calculated for the samples using the a* and b* values, but they did not show any significant difference between the groups. Hoffman (2000b) recorded similar colorimetric values of *L = 29.22, *a = 11.26 and *b = 7.76 for impala that were also cropped at night.

It is well known that game meat is darker in colour than other meat. The darker colour of game meat may be ascribed to the elevated levels of myoglobin present in the muscle (Vestergaard *et al.*, 2000; Diaz *et al.,* 2002). This elevated myoglobin content and thus darker meat colour is possibly due to the fact that wild ungulates are much more active than domesticated animals such as cattle and sheep. Studies have shown that there is an increase in myoglobin concentrations in muscle as a result of systematic exercise (Lawrie, 1998; Vestergaard *et al.*, 2000; Diaz *et al.,* 2002). However, the darker colour of the meat may also, in part, be as a result of the relatively less intra-muscular fat present (Janicki *et al.*, 1963), since it has been found that the impala has less intra-muscular fat than domestic livestock (Hoffman, 2000a). When carcasses have a higher (≥ 5.7) pH_u, light transmittance through the fibres is high and the diffusion of that light is small, so meat

colour appears darker (Swatland, 1990). It is likely that the darker colour of game meat makes it difficult to measure possible subtle differences in the colour that may have arisen as a result of marginally stressful conditions.

Consumer perception of game meat in South Africa is often unfavourable because of its dark colour (Von la Chevallerie, 1972). This has a negative effect on its popularity because many consumers prefer meat that is neither dark nor pale (Jeremiah *et al.,* 1972). Dark, firm and dry (DFD) meat is a common occurrence with game meat because of the often highly stressful conditions in which game is harvested. Hoffman (2000b) recorded values of L* = 25.44, a* = 9.13 and b* = 4.88 for a male animal that was wounded and subsequently subjected to severe ante mortem stress for a period of 10 minutes. The animal had the darkest meat and the fastest pH decline and was said to have the DFD condition. All of the animals cropped in this study were in a calm state directly prior to cropping. So it is unlikely that any of them experienced the type of circumstances conducive to the DFD condition. Their relatively higher colorimetric values (Table 3) than those reported for the stressed animal by Hoffman (2000a) are evidence of this.

Table 3 Colorimetric values (LSMean ± s.e.) for the day (n = 24) and night (n = 16) cropped impala

	Day cropped	Night cropped	P > |t|
L*	30.53 ± 2.758	30.10 ± 1.296	0.50
A*	12.52 ± 1.361	13.19 ± 1.475	0.15
b*	8.75 ± 1.422	9.42 ± 1.780	0.20
C*	15.85 ± 2.159	15.99 ± 1.856	0.80
h_{ab}	0.59 ± 0.084	0.62 ± 0.058	0.20

Conclusions

The results of the pH data, drip loss and shear force analyses clearly show that night cropping yields a better meat quality than day cropping. The slower rate of pH decline of the night cropped group shows that conditions during night cropping are more favourable for meat quality than day cropping. Night cropping does not seem to have any detrimental effects on meat quality and it can be deduced that this is as a result of lower ante mortem stress to the animals.

Owing to the very low night-time ambient temperatures, it is possible that animals cropped at night could develop cold shortening. However, this specific aspect requires further research.

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