GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF DORPER WETHER LAMBS FED *OPUNTIA*-BASED DIETS WITH DIFFERENT NITROGEN SOURCES IN THE FEEDLOT

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ABSTRACT

The growth performance and carcass characteristics of Dorper wether lambs fed *Opuntia*-based diets with different nitrogen sources were evaluated in the feedlot. A total of 45 newly weaned Dorper wether lambs, weighing on average about 22 kg, were randomly allocated to the three treatment diets. Fifteen Dorper wether lambs per treatment diet were further subdivided into three subgroups or replicates of five lambs each. The three treatment diets consisted of a conventional feedlot diet (treatment diet T0) and two *Opuntia*-based treatment diets (T1 and T2) containing different additional nitrogen sources, namely a non-protein nitrogen (NPN; feed grade urea) or natural protein (sunflower oilcake meal). Each Dorper wether lamb was weighed at the beginning of the experiment and every week after that to determine the average daily gain. All lambs were slaughtered when they reached an average target weight of 35 kg live body weight for determining carcass characteristics. The final live body weight and total weight gain was similar *(P* > 0,05) for all treatment groups. The Dorper wether lambs fed treatment diet T0 and T2 had higher (*P* < 0,05) ADG and better (*P* < 0,05) efficiency of gain than Dorper wether lambs fed on treatment diet T1. The carcass weights did not differ significantly *(P* > 0,05) among treatment diets. The dressing percentage was however slightly *(P* > 0,06) higher for Dorper wether lambs fed the *Opuntia*-based diets (T1 and T2) than those fed the conventional diet (T0). Except for the external carcass length, shoulder circumference and pH24, all carcass measurements were similar *(P* > 0,05) across all treatments. Dorper lambs fed treatment diet T2 had the longest (*P* < 0,05) external carcass length and T1 recording the shortest carcass. Shoulder circumference was higher for T0 than T1 and T2. Although the pH24 was lower (*P* < 0,05) for T0 compared to T1 and T2, all measured pH values were within the normal range of 5,4 to 5,7. The lack of significant differences in most of the carcass characteristics considered in this study suggest that carcass quality is not markedly affected by inclusion of sun-dried and coarsely ground *Opuntia cladodes* in feedlot diets or by the type of nitrogen source used. The marked difference in ADG and FCR between *Opuntia*-based diets indicated the impor-tance of a high quality nitrogen source in efficient mutton and lamb production. However the economics of feeding such diets should be worked out to determine which one will give the best economic return.

INTRODUCTION

Commercial lamb and mutton production is an important part of the livestock industry in South Africa and Namibia. Weaned lambs as well as culled ewes and rams are sold to feedlots where they are fattened to improve carcass grading quality before being slaughtered. The feedlot diets invariably include good quality roughage such as lucerne hay. Therefore, it is common to use short intensive feeding periods to fatten or "round off" animals before slaughtering. This is done at feedlots both on farm or at specialised enterprises.

Over the past decade, sun-dried and coarsely ground Opuntia cladodes have been used experimentally as a feed source for ruminants. Previous studies by Zeeman (2005), Einkamerer (2008) and Menezes (2008) at the University of the Free State, Bloemfontein clearly demonstrated that sun-dried and coarsely ground *Opuntia cladodes* can replace a substantial part of lucerne hay (up to an inclusion level of 360 g/kg) in diets for young Dorper wether lambs.

The growth performance and carcass characteristics are important when finishing lambs in a feedlot. These aspects have been reported for Dorper lambs under intensive conditions by Milne (2000), Cloete ***et al.*** (2000), Staab ***et al.*** (1999), Notter ***et al.*** (2004), Snowder and Duckett (2003) and Daniel and Held (2005). However, none of these studies have used *Opuntia* as part of the feedlot diets. Therefore, this study focused on evaluating two feedlot diets for Dorper wether lambs, containing inclusion levels of about $^1/_3$ sun-dried and coarsely ground *Opuntia cladodes* of the total diet and two different nitrogen sources (NPN and a natural protein).

MATERIALS AND METHODS

Study area

The study was conducted at Bergvlug Experimental Farm, Directorate of Veterinary Services, Ministry of Agriculture, Water and Forestry, Khomas Region, Namibia. The field work lasted from February to June 2009 with the approval of the Interfaculty Animal Ethics Committee of the UFS (Animal experiment No. 02/09; dated 27 May 2009).

Experimental animals and management

The Dorper wether lambs used in this study were the property of the Directorate of Agricultural Research and Training, in the Ministry of Agriculture, Water and Forestry, Namibia. The 45 newly weaned Dorper wether lambs with an average live weight of 22 kg were transferred from the Hardap Research Station, near Mariental, to Bergvlug Experimental Farm where the trials were conducted. Upon arrival at Bergvlug, the Dorper wether lambs were identified with a numbered ear tag and vaccinated with Multivax P at the beginning of the trials to protect them against botulism, black quarter, pulpy kidney and clostridium. They were also treated against internal parasites.

The 45 Dorper wether lambs were stratified according to live weight into nine groups of five lambs, thus ensuring comparable mean initial weights for groups. Three replicates or subgroups of five lambs were then randomly allocated to each of the three treatment diets resulting into a complete randomized design. For the duration of the trial the Dorper wether lambs were kept in a shaded area (open-sided roofed shed) and received the different treatment diets and fresh water daily *ad libitum*.

Treatment diets and feeding

The three treatment diets consisted of a conventional feedlot diet (treatment diet T0) and two *Opuntia*-based treatment diets (T1 and T2) containing different additional nitrogen sources, namely a non-protein nitrogen (NPN; feed grade urea) or natural protein (sunflower oilcake meal). Treatment diet T0 was based on coarsely ground lucerne hay, yellow maize meal, feed grade urea and molasses meal. The *Opuntia*-based treatment diets (T1 and T2) were reformulated and some of the lucerne was replaced by sun-dried and coarsely ground *Opuntia cladodes* at levels of 330 g/kg or 300 g/kg. In treatment diet T1 additional nitrogen was included as feed grade urea (non-protein nitrogen; NPN) and for treatment diet T2 the additional nitrogen was included as sunflower oilcake meal (a natural protein).

The composition of the three treatment diets is presented in Table 1.

The Dorper wether lambs were given two weeks for adaptation to the respective diets before the beginning of data collection.

Each Dorper wether lamb was weighed at the beginning of the experiment and thereafter every week to determine the average daily gain. All lambs were slaughtered when they reached an average target weight of 35 kg live body weight for determining carcass characteristics.

Table 1. Composition of the three treatment diets (T0, T1 and T2) fed to Dorper wether lambs

	Treatment diets*		
Feed ingredient (kg air dry)	T0	T1	T2
Sun-dried and coarsely ground *Opuntia cladodes*	–	330	300
Coarsely ground lucerne hay	577	255	190
Yellow maize meal	358	340	275
Feed grade urea	10	20	–
Sunflower oilcake meal	–	–	180
Molasses meal (Enermol)	40	40	40
Feed lime	15	15	15

* T0: conventional feedlot diet; T1: *Opuntia*-based diet (330 g/kg sun-dried and coarsely ground *Opuntia cladodes* with NPN); T2: *Opuntia*-based diet (300 g/kg sun-dried and coarsely ground *Opuntia cladodes* with Natural protein).

Chemical analysis of feeds, refusals and faeces

All composite samples (faeces, feeds and refusal) were dried in at 100 °C in an oven and prepared for analysis by grinding it in a hammer mill to pass through a 1 mm sieve. Concentration of dry matter (DM), crude protein (CP; AOAC, 2000), ash, organic matter (OM), acid detergent fibre (ADF), neutral detergent fibre (NDF; Goering and Van Soest (1970) and Robertson and Van Soest, 1981), lipids and gross energy in diet, feed refusal and faeces were determined. Apparent digestibility coefficient of DM, Ash, OM, ADF, NDF, lipids and GE were also calculated.

Data analysis

Data were subjected to analysis of variances (ANOVA) using the General Linear Model (GLM) procedures of SAS (2006). The effects of the treatments on feed and water intake and digestibility were assessed.

RESULTS AND DISCUSSIONS

Growth performance of Dorper wether lambs

The live body weight changes of Dorper wether lambs fed treatment diets T0 and T2 were slightly higher $(P > 0{,}05)$ than those fed treatment diet T1 (Figure 1), but their growth curves were very similar until the end of the feeding trial period.

The average initial body weight of the Dorper wether lambs was the same for all three treatment diets (Table 2), but the Dorper wether lambs fed treatment diets T0 and T2 reached the target weight of 35 kg for slaughtering after about 11 weeks. Two weeks later the Dorper wether lambs fed treatment diet T1 were still weighing on average only about 32,5 kg (Table 2) and it was decided to slaughter them. However, in terms of live body weight changes, there were no significant differences $(P > 0{,}05)$ among treatments.

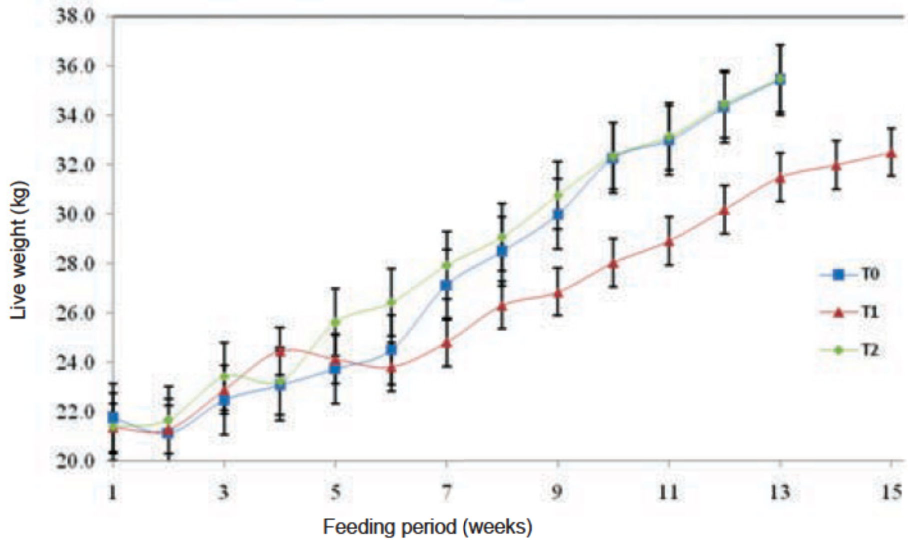

Figure 1. Average live body weight of Dorper wether lambs during the feeding period in the feedlot.

Table 2. Performance of the Dorper wether lambs during the feeding period in the feedlot and the cost of diets

Variable	Treatment diets *			P^1	CV^2 (%)
	T0	T1	T2		
Initial live body weight (kg)	21,23 ± 0,55[a]	21,13 ± 0,46[a]	21,67 ± 0,50[a]	0,730	9,13
Final live body weight (kg)	35,46 ± 0,11[a]	32,43 ± 0,53[a]	35,60 ± 0,64[a]	0,057	11,0
Total weight gain (kg)	13,90 ± 0,41[a]	11,30 ± 0,09[a]	13,93 ± 0,32[a]	0,064	25,6
Average daily weight gain (ADG) (g)	180,6 ± 3,7[a]	125,4 ± 0,8[b]	181,0 ± 2,9[a]	< 0,001	24,6
Feed intake (kg DM/day/head)	1,147 ± 0,050[a]	1,131 ± 0,071[a]	1,209 ± 0,022[a]	0,538	7,3
FCR (kg DM intake/kg gain)	6,07 ± 0,73[b]	8,25 ± 0,27[a]	6,11 ± 0,16[b]	0,036	10,9
Cost of diet/kg (N$)	3,14 ± 0,01[a]	2,42 ± 0,02[b]	2,70 ± 0,01[b]	0,001	0,9
Cost of diet/head/day (N$)	3,71 ± 0,18[a]	2,73 ± 0,19[b]	3,26 ± 0,01[b]	0,007	5,7
Feeding period (days)	77	91	77		

* T0: conventional feedlot diet; T1: *Opuntia*-based diet (330 g/kg sun-dried and coarsely ground *Opuntia cladodes* with NPN); T2: *Opuntia*-based diet (300 g/kg sun-dried and coarsely ground *Opuntia cladodes* with Natural protein)

[a,b] Means with different superscripts within a row are significantly different ($P < 0,05$)

[1] Probability

[2] Coefficient of variance

The observations in this study on the live body weight of Dorper wether lambs fed *Opuntia*-based diets were in agreement with the findings by Zeeman (2005), Einkamerer (2008) and Menezes (2008). Their studies showed that the inclusion of 360 g/kg sun-dried and coarsely ground *Opuntia cladodes* in diets did not have a significant effect on the live body weight of Dorper wether lambs. However, it must be noted that the Dorper wether lambs used in the studies by Zeeman (2005), Einkamerer (2008) and Menezes (2008) were older and also heavier than those used in this study. Therefore, comparisons of animal performance must be viewed with caution.

In this study, the average daily gain (ADG) of the young Dorper wether lambs (Table 2) was significantly ($P < 0,05$) lower for Dorper wether lambs fed treatment diet T1 compared to those fed treatment diets T2 and T0.

When comparing the two Opuntia-based diets (T1 and T2), the ADG was significantly higher ($P < 0,05$) for lambs fed the diet containing natural protein (T2) (Table 2) than for those fed the diet with NPN (T1). Degu *et al.* (2008) reported similar results, namely that plant oilcake meals enhanced the growth performance of lambs on *Opuntia*-based diets.

The differences in ADG observed between treatment diets T1 and T2 could be partially attributed to the quality of N sources, specifically the amino acid profile, used to balance the *Opuntia*-based diets. Feed grade urea, an NPN source, was included in treatment diet T1 and sunflower oilcake meal (a source of natural plant protein) was included in treatment diet T2. Unlike the NPN source, the natural protein source provided amino acids and promoted better growth in animals. Newly weaned young lambs that had recently still been suckling, may still have been lacking in development of the reticulo-rumen and would therefore, still more dependent on dietary amino acids. As emphasised by Schilling (2005), protein is an essential dietary element that is necessary for proper soft tissue development in growing lambs and sufficient protein should therefore be provided to promote the desired growth rates.

It has been well documented (Sirohi *et al.*, 1997; Ben Salem *et al.*, 2002; 2004; Misra *et al.*, 2006; Tegegne *et al.*, 2005) that *Opuntia cladodes* have a low protein content and therefore additional N should be included in *Opuntia*-based diets to improve its nutritive value. Mendez-Llorente *et al.* (2008) observed improved growth by lambs fed an *Opuntia*-based diet containing fish meal. A similar observation was made by Misra *et al.* (2006) when groundnut meal was included in an *Opuntia*-based diet. Therefore, the results of the current study are in agreement regarding the positive effects of the inclusion of a natural protein source in *Opuntia*-based diets to promote growth of lambs.

Level of feed intake can have a great affect on the cost of livestock production (Schilling, 2005). This author stated that although a lower daily feed intake results in corresponding decreases in the cost of feeding, it also reduces average daily gain (ADG) and increases the number of days required to reach the target weight. As shown previously in Table 2, the Dorper wether lambs fed treatment diets T0 and T2 had higher ADG's and thus required fewer days to reach the target slaughter weight than Dorper wether lambs fed treatment diet T1. Furthermore, the Dorper wether lambs fed treatment diet T1 (containing NPN) failed to reach the target average body weight of 35 kg. It was therefore decided to slaughter these Dorper wether lambs after 91 days in the feedlot at an average body weight of 32,5 kg.

Efficiency of gain or feed conversion ratio (FCR) is another important determinant of feedlot efficiency. According to Schilling (2005), a decrease in the quantity of feed needed by an animal to reach a target weight may increase profitability. The results presented in Table 2 show that the Dorper wether lambs fed treatment diets T0 and T2 had a similar FCR, but these FCR's were significantly better ($P < 0,05$) than those fed treatment diet T1. Thus, the Dorper wether lambs fed treatment diet T1 required more feed than those fed treatment diets T0 and T2 to gain the same live body weight in the feedlot.

The basic information used for estimating the cost of the diets (Table 2) was derived mainly from the prices of different ingredients used to formulate the treatment diets and the quantity of feed eaten by the Dorper wether lambs during the feeding periods in the feedlot.

The information presented in Table 2 was used to estimate the cost of feeding one Dorper wether lamb a conventional feedlot diet (treatment diet T0) to reach a target slaughter weight of 35 kg after 77 days. This amounts to a total feed cost of N$278.20 per head. However, it required N$26.96 less in feed cost for a lamb fed treatment diet T2 to reach the target slaughter weight of 35 kg after the same feeding period of 77 days. Although it took longer (91 days) for Dorper wether lambs fed treatment diet T1 to approach the target slaughter weight, the feed costs were less than for treatment diets T0 and T2, namely N$29.39 and N$2.43 per head respectively. This can be partly explained by the lower unit cost of diets and cost of diet per head per day for treatment diet T1 compared to treatment diets T0 and T2.

CARCASS EVALUATION

Carcass weight and dressing percentage

Carcass characteristics of the Dorper wether lambs in the three treatment groups (T0, T1 and T2) are presented in Table 3. The hot and cold carcass weights did not show significant differences ($P > 0,05$) among treatment diets. This was expected because the target live weight of 35 kg was predetermined. The dressing percentage was, however, slightly ($P < 0,06$) higher for Dorper wether lambs fed the Opuntia-based treatment diets (T1 and T2) than those fed the conventional feedlot diet (T0).

Results of carcass weight for Dorper wether lambs fed Opuntia-based diets at an inclusion level of 300 g/kg to 330 g/kg were slightly lower than those (17,77 kg) reported by Einkamerer (2008) at a similar inclusion level of sun-dried and coarsely ground *Opuntia cladodes*. However, the Dorper wether lambs in the study by Einkamerer (2008) were older and heavier than those used in the present study.

Carcass value characteristics (grading)

Carcass value characteristics (grading) were assessed according to visible subcutaneous fat cover and leanness of the meat. According to Snowder & Duckett (2003), the fat cover over the musculus longissimus dorsi is a very important aspect of the carcass grading and value.

In addition, Louvandini *et al.* (2006) stated that a fattening score and conformation of carcasses are criteria that define carcass quality. Carcasses finished with good conformation tend to fetch a better price per kilogramme at sale, especially in countries with a tradition of lamb and mutton production, as it is the case for Namibia and South Africa.

In this study, fatness score and conformation did not differ significantly ($P > 0,05$) among treatment diets (Table 3). After visual evaluation of the fatness score, all carcasses of the Dorper wether lambs in the three treatment diets fell between the second and the third quality grades, in the score range of 2,43 to 2,86. For conformation score, the carcasses varied from a score of 3,86 to 4,36. Moreover, the fatness score and the average fat thickness of Dorper wether lambs fed treatment diet T1 tended to be numerically slightly higher than for treatment diets T0 and T2 (Table 3).

The carcass quality grades and prices obtained by Dorper wether lambs are shown in Table 4. Most of the Dorper wether lambs fed treatment diets T2 and T0 obtained the highest possible grade (A2), with 66,7 % of the lambs in

Table 3. Slaughter weight and carcass characteristics of the Dorper wether lambs fed three treatment diets in a feedlot

Variables	Treatment diets *			P^1	CV^2 (%)
	T0	T1	T2		
Carcass weight and dressing percentage					
Slaughter weight (kg)	35,46 ± 0,06^a	32,53 ± 0,55^a	35,57 ± 0,61^a	0,057	11,0
Hot carcass weight (kg)	16,77 ± 0,36^a	16,33 ± 0,54^a	17,69 ± 0,51^a	0,133	10,5
Cold carcass weight (kg)	16,26 ± 0,06^a	15,85 ± 0,12^a	17,16 ± 0,17^a	0,130	10,8
Hot carcass dressing (%)	47,30 ± 0,17^b	50,62 ± 0,67^a	49,62 ± 0,44^a	0,006	5,3
Carcass value characteristics (grading)					
Fatness code (score 0 to 6)	2,57 ± 0,23^a	2,86 ± 0,23^a	2,43 ± 0,17^a	0,357	30,3
Conformation (score 1 to 5)	4,36 ± 0,20^a	3,86 ± 0,27^a	3,86 ± 0,14^a	0,171	19,7
Carcass measurements					
Carcass external length (cm)	55,59 ± 0,75^a	51,65 ± 1,07^b	57,13 ± 0,52^a	< 0,001	5,5
Shoulder circumference (cm)	29,16 ± 0,61^a	26,11 ± 0,39^a	23,54 ± 1,64^b	0,002	14,7
Buttock circumference (cm)	41,71 ± 0,42^a	41,59 ± 0,60^a	41,36 ± 0,77^a	0,920	5,5
Musculus longissimus dorsi width (cm)	5,63 ± 0,20^a	5,86 ± 0,20^a	5,85 ± 0,07^a	0,113	5,7
Musculus longissimus dorsi depth (cm)	2,78 ± 0,07^a	2,96 ± 0,11^a	2,87 ± 0,08^a	0,354	10,9
pH1^3	5,84 ± 0,07^a	5,71 ± 0,01^a	5,76 ± 0,08^a	0,425	4,8
pH24^4	5,54 ± 0,05^a	5,62 ± 0,02^b	5,65 ± 0,03^b	0,021	2,0
Fat thickness					
Fat thickness was measured at ¼ position on the 12th rib from the chine bone end	2,93 ± 0,32^b	4,54 ± 0,61^a	3,91 ± 0,29^a	0,042	43,1
Fat thickness was measured at ½ position on the 12th rib from the chine bone end	6,32 ± 0,99^a	4,17 ± 0,51^b	4,00 ± 0,45^b	0,041	53,6
Fat thickness was measured at ¾ position on the 12th rib from the chine bone end	6,76 ± 0,83^a	8,35 ± 0,91^a	7,31 ± 0,59^a	0,362	39,3
Average fat thickness	5,34 ± 0,06^a	5,69 ± 0,07^a	5,08 ± 0,13^a	0,746	40,6

* T0: conventional feedlot diet; T1: *Opuntia*-based diet (330 g/kg sun-dried and coarsely ground *Opuntia cladodes* with NPN); T2: *Opuntia*-based diet (300 g/kg sun-dried and coarsely ground *Opuntia cladodes* with Natural protein)

a,b Means with different superscripts within a row are significantly different ($P < 0,05$)

1 Probability

2 Coefficient of variance

3 pH of the carcass taken 1 hour after slaughter

4 pH of the carcass taken 24 hours after slaughter

Table 4. Carcass grades and prices per kg obtained by the Dorper wether lambs fed the three treatment diets

Carcass grades obtained (%)	Treatment diets*		
	T0 (%)	TI (%)	T2 (%)
A2	53,8	36	66,7
A3	38,5	50	26,7
A4	7,7	7	6,7
A5	–	7	–
Carcass price (N$/kg)	23,80	23,67	24,35

* T0: conventional feedlot diet; T1: *Opuntia*-based diet (330 g/kg sun-dried and coarsely ground *Opuntia cladodes* with NPN); T2: *Opuntia*-based diet (300 g/kg sun-dried and coarsely ground *Opuntia cladodes* with Natural protein)

Table 5. Proportion of the muscle, bone and fat of the 3-rib cut from carcasses of the Dorper wether lambs

Tissue (%)	Treatment diets *			P^1	CV^2 (%)
	T0	T1	T2		
Muscle	54,34 ± 0,35^a	51,33 ± 0,42^a	49,72 ± 0,77^a	0,087	10,5
Fat	25,00 ± 0,80^b	25,20 ± 0,00^b	31,30 ± 0,80^a	0,026	24,6
Bone	20,62 ± 0,44^a	23,45 ± 0,45^a	18,97 ± 0,01^a	0,146	28,3

* T0: conventional feedlot diet; T1: *Opuntia*-based diet (330 g/kg sun-dried and coarsely ground *Opuntia cladodes* with NPN); T2: *Opuntia*-based diet (300 g/kg sun-dried and coarsely ground *Opuntia cladodes* with Natural protein)

a,b Means with different superscripts within a row are significantly different ($P < 0,05$)

1 Probability

2 Coefficient of variance

treatment diet T2 and 53,8 % in treatment diet T0. Of the Dorper wether lambs fed treatment diet T1, 50 % obtained the second highest possible carcass quality grade (A3).

Based on the grading of carcasses, Dorper wether lambs fed treatment diet T2 on average obtained the highest price of N$24.35/kg, while those fed treatment diets T0 and T1 on average obtained N$23.80/kg and N$23.67/kg respectively (Table 4).

Carcass measurements

Except for the external carcass length, shoulder circumference and pH24 (Table 3), there were no significant differences *(P* > 0,05) in all other carcass measurements between the Dorper wether lambs on the different treatment diets. The external carcass length of the Dorper wether lambs was significantly different (*P* < 0,001), with treatment diets T2 and T0 being the longest and treatment diet T1 recording the shortest carcasses. These values are in line with the differences in ADG (Table 2). The values for shoulder circumference were higher (*P* < 0,05) for Dorper wether lambs fed treatment diet T0 than the two *Opuntia*-based diets, with Dorper wether lambs fed on treatment diet T2 being the lowest.

The results in Table 3 also indicate that pH measured in the left *musculus longissimus dorsi* of the carcasses 1 hour (pH1) after slaughtering were similar *(P* > 0,05) for all treatment diets. However, pH measured 24 hours (pH24) post-mortem was significantly (*P* < 0,05) lower for carcasses of Dorper wether lambs fed treatment diet T0 compared to those fed treatment diets T1 and T2. According to Lapenga *et al.* (2009), the pH usually indicates the preservation quality of the meat and that good quality meat usually has a pH of 5,4 to 5,7. Although there were significant differences (*P* < 0,05) between treatments after 24 hours, the pH24 values were all within the normal range.

The ultimate pH, also referred to as the final pH of the meat, is usually reached 24 hours post-mortem. This pH is attained either by depletion of glycogen reserves in muscles or when the pH has reached a point at which enzymes become inactive (Jeremiah *et al.*, 1991; Sebsibe, 2009). Deviation from a normal pH range has the potential to produce carcasses that are more susceptible to microbial contamination.

Fat thickness

Average fat thickness over the *musculus longissimus dorsi* taken at three different positions on the 12th rib obtained in this study (Table 3) were not significantly *(P* > 0,05) different.

However, fat thickness varied across the three different positions over the m*usculus longissimus dorsi* (or the eye muscle) on the 12th rib (Table 3), which could suggest a trend of uneven distribution of subcutaneous fat over the loin. Daniel and Held (2005) observed a fat thickness of 5,5 mm between the 12th and 13th rib in Dorper-sired lambs with an average carcass weight of 26,6 kg. However, irrespective of the nutritional influence, Cloete *et al.* (2000) reported that Dorper sheep are early maturing and capable of depositing fat at an early age and lighter weight than most other mutton breeds in South Africa.

Carcass composition

Daskiran *et al.* (2006) emphasised that tissue analysis for experimental purposes on whole or half carcasses requires much more time and labour besides the economical loss incurred when selling carcasses from this type of trial than when estimates are used. Therefore, only a 3-rib cut (9th to 11th ribs) was used for tissue analysis in this study in order to speed up analysis and cost-effective determination of tissue composition (Table 5).

Although slight variations were observed, the treatment effect was not significant when the proportions of muscle and bone were expressed as a percentage of the 9th through 11th rib cut. However, with regard to tissue, the fat composition of carcasses of Dorper wether lambs fed treatment diet T2 was significantly (*P* < 0,05) higher than those fed treatment diets T0 and T1. Nevertheless, the carcasses were given a similar carcass grading, regardless of the treatment diet used. This means that although there were differences in tissue composition, it had no effect on the carcass grading.

CONCLUSION

The lack of significant differences in most of the carcass characteristics considered in this study suggest that carcass quality is not markedly affected by inclusion of sun-dried and coarsely ground *Opuntia cladodes* in feedlot diets (up to 300 g/kg or 330 g/kg) for Dorper wether lambs or by the type of nitrogen source used. Thus, the carcasses of the Dorper wether lambs fetched very similar prices per kg. The Dorper wether lambs fed treatment diet T1 were not able to reach the average target slaughter weight of 35 kg. The marked difference in ADG and FCR between *Opuntia*-based diets indicated the importance of a high quality nitrogen source in efficient mutton and lamb production. However the economics of feeding such diets should be worked out to determine their economic returns.

REFERENCES

AOAC, 2000. Official Methods of Analysis of AOAC International. Vol.1. 17th Edn. Editor Horwitz, W. AOAC International®.

AGRI LABORATORY ASSOCIATION OF SOUTHERN AFRICA (AgriLASA), 2007. Plant and Feed Analysis.

BEN SALEM, H., NEFZAOUI, A., & BEN SALEM, L., 2002. Supplementing spineless cactus (*Opuntia ficus indica* var. *inermis*) based diets with urea-treated straw or oldman saltbush (*Atriplex nummularia*). Effect on intake, digestion and sheep growth. *Journal of Agricultural Science* 138, 85–92.

BEN SALEM, H., NEFZAOUI, A. & BEN SALEM, L., 2004. Spineless cactus (*Opuntia ficus-indica* var. *inermis*) and oldman saltbush (*Atriplex nummularia L.*) as alternative supplements for browsing Barbarine lambs given straw-based diets. *Small Ruminant Research* 51, 65–73.

CLOETE, S.W.P., SNYMAN, M.A. & HERSELMAn, M.J., 2000. Productive performance of Dorper sheep. *Small Ruminant Research* 36, 119–35.

DANIEL, J.A. & HELD, J., 2005. Carcass and growth characteristics of wethers sired by White Dorper or Hampshire Rams. *Sheep and Goat Research Journal* 20, 47–50.

DASKIRAN, M., BINGOL A., KOR A., DEMIR A.O, YILMAZ, A. & KARACA S., 2006. Feedlot performance and carcass characteristics of Norduz male kids. *Journal of Animal Veterinary Advances* 5 (5), 430–433.

DEGU, A., MELAKU, S. & BERHANE, G., 2008. Supplementation of isonitrogenous oil seed cakes in cactus (*Opuntia ficus-indica*)–tef straw (*Eragrostis* tef) based feeding of Tigray Highland sheep. *Animal Feed Science Technology* 148, 214–226.

EINKAMERER, O.B., 2008. Animal performance and utilization of *Opuntia*-based diets by sheep. M.Sc. Agric. Thesis. University of the Free State, Bloemfontein, South Africa.

GOERING, H.K. & VAN SOEST, P.J., 1970. Forage fibre analysis. U.S.D.A. *Agricultural Handbook* 379.

JEREMIAH, L.E., TONG, A.K. & GIBSON, L.L., 1991. The usefulness of muscle color and pH for segregating beef carcasses into tenderness groups. *Meat Science* 30, 97–114.

LAPENGA, K.O., EBONG, C. & OPUDA-ASIBO, J., 2009. The effect of feed supplements on weight and carcass characteristics of intact male Mubende goats fed elephant grass (*Pennisetum purpureum*) *ad libitum* in Uganda. *Journal of Animal Veterinary Advances* 8 (10), 2004–2008.

LOUVANDINI, H., MCMANUS, C., DALLAGO, B., DE OLIVEIRA MACHADO, S. & ANTUNES, D.A., 2006. Evaluation of carcass traits, non-carcass components and 12th rib analysis of hair sheep supplemented with phosphorus. *Soiedade Brasileira de Zootecnia* 35 (2), 550–555. Available online at www.sbz.org.br.

MAREKO, M.H.D., AGANGA, A.A., OMPILE, U.J. & MOKHUDU, M., 2006. Carcass characteristics and Meat composition of yearling Tswana Goats Fed *Teminalia sericea*, *Boscia albitrunca* browses or lucerne as supplements. *Journal of Animal Veterinary. Advances* 5 (11), 964–969.

MENEZES, C.M.D.C., 2008. Effects of sun-dried *Opuntia ficus-indica cladodes* on digestive processes in sheep. M.Sc. Agric. Thesis. University of the Free State, Bloemfontein, South Africa.

MENDEZ-LLORENTE, F., RAMÍREZ-LOZANO, R.G., AGUILERA-SOTO, J.I. & ARECHIGA-FLORES, C.F., 2008. Performance and nutrient digestion of lambs fed incremental levels of wild cactus (*Opuntia leucotrichia*), Conference on International Research on Food Security, Natural Resource Management and Rural Development, University of Hohenheim.

MILNE, C., 2000. The history of the Dorper sheep. *Small Ruminant Research* 36, 99–102.

MISRA, A.K., MISHRA, A.S., TRIPATHI, M.K., CHATURVEDI, O.H., VAITHIYANATHAN, S., PRASAD, R. & JAKHMOI, R.C., 2006. Intake, digestion and microbial protein synthesis in sheep on hay supplemented with prickly pear cactus [*Opuntia ficus-indica* (L.) Mill.] with or without groundnut meal. *Small Ruminant Research* 63, 125–134.

NOTTER, D.R., GRENIER, S.P. & WAHLBERG, M.L., 2004. Growth and carcass characteristics of lambs sired by Dorper and Dorset rams. *Journal Animal Science* 82, 1323–1328.

ROBERTSON, J.B. & VAN SOEST, P.J., 1981. The detergent system of analysis and its application to human foods. In: The analysis of dietary fibre. Eds. James, W.P.T. & Theander, O. Dekker, New York.

SAS, 2006. SAS® User's Guide. Version 6.12. SAS Institute Inc., Cary, NC., USA.

SCHILLING, B.S., 2005. Performance evaluation, carcass characterization and palatability assessment of hair sheep. M.Sc. Thesis. Texas Tech. University, USA.

SEBSIBE, A., 2009. Chapter 5: Sheep and goat meat characteristics and quality, sheep and goats production handbook for Ethiopia. Available on line: http://www.esgpip.info/HandBook/Handbook_PDF/Chapter 12_Sheep and Goat meat characteristics and quality.pdf. (Downloaded on 26/10/2009.)

SIROHI, S.K., KARIM, S.A. & MISRA, A.K., 1997. Nutrient intake and utilization in sheep fed with prickly pear cactus. *Journal of Arid Environments* 36, 161–166.

SNOWDER, G.D. & DUCKETT, S.K., 2003. Evaluation of the South African Dorper as a terminal sire breed for growth, carcass, and palatability characteristics. *Journal of Animal Science* 81, 368–375.

STAAB, K.A., HESS, B.W., MEANS, W.J., NEL, J.E. & CECIL, J.T., 1999. Feedlot performance and carcass differences among Dorper, Suffolk, and Western white-faced sired lambs. *Journal of Animal Science* 77, 105–106.

TEGEGNE, F., PETERS, K.J. & KIJORA, C., 2005. Cactus pear (*Opuntia ficus indica*): a strategic crop in combating food and feed insecurity and desertification in Tigray, Northern Ethiopia. *Proceedings Society of Nutrition Physiology* 14, 60.

ZEEMAN, D.Z., 2005. Evaluation of sun-dried *Opuntia ficus-indica* var. *Algerian cladodes* in sheep diets. M.Sc. Agric. Thesis. University of the Free State, Bloemfontein, South Africa.