THE EFFECTS OF *OPUNTIA*-BASED DIETS WITH DIFFERENT NITROGEN SOURCES ON FEED INTAKE AND DIGESTIBILITY BY DORPER WETHER LAMBS IN THE FEEDLOT

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ABSTRACT

The feed intake and digestibility of *Opuntia*-based diets with different nitrogen sources by Dorper wether lambs were evaluated in the feedlot. 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). A total of 45 newly weaned Dorper wether lambs, weighing on average about 22 kg, were randomly allocated to the three treatment diets. The 15 Dorper wether lambs per treatment diet were further subdivided into three subgroups or replicates of five lambs each. The Dorper wether lambs were fed the treatment diets until a target average slaughter weight of 35 kg per treatment diet was reached. During the feeding period in the feedlot, one replicate of five Dorper wether lambs per treatment diet was moved from the feedlot pens to metabolism cages for a week every third week to determine their individual daily feed and water intake and apparent digestibility of the three treatment diets. The daily urine and faecal excretions were also monitored.

The results of the study confirmed that the feed intake and apparent digestibility of the treatment diets for Dorper wether lambs were not affected by: (1) the inclusion of sun-dried and coarsely ground *Opuntia cladodes* at 330 g/kg and 300 g/kg; or (2) two nitrogen sources used (NPN or natural protein) in the *Opuntia*-based diets. Therefore, sun-dried and coarsely ground *Opuntia cladodes* could substitute lucerne in the feedlot diets of Dorper wether lambs up to 330 g/kg. However, because of the relative low CP content of *Opuntia cladodes*, additional nitrogen can be supplied as either NPN or natural protein to balance the nitrogen content of *Opuntia*-based diets and maintain a final CP level required to promote a desired growth.

INTRODUCTION

Commercial lamb and mutton production is an important part of the livestock industry in South Africa and Namibia. Most commercial farmers use extensive production systems and sell weaned lambs as well as culled ewes and rams. Due to the extensive nature of the production systems as well as the seasonality of the rainfall and its effects on quantity and quality of grazing, these sheep are often not ready or fat enough to be marketed. Therefore, it is common practice to use short intensive feeding periods to fatten or "round off" animals to improve carcass grading before slaughtering. This is done in feedlots both on farms or at specialised enterprises.

Feedlot diets invariably incorporate substantial quantities of good quality roughage such as lucerne hay. Lucerne has a high demand for water and therefore it is mostly produced commercially under irrigation. Since water resources are becoming increasingly scarce and expensive, an important feed such as lucerne is also becoming increasingly scarce and expensive, thus limiting the profitability of sheep feedlot operations. Therefore, there is a need to identify and develop affordable alternative feed sources for ruminant feedlot diets.

Over the past decade, sun-dried and coarsely ground *Opuntia cladodes* have been used experimentally as a feed source for ruminants. According to Santos *et al.* (2003) and Khalafalla *et al.* (2007), the increased importance of cactus pear in tropical and subtropical regions is mainly due to their drought resistance, high biomass yield, palatability, salinity tolerance and soil adaptability. These factors make *Opuntia* species an important feed source for livestock, particularly during periods of drought and seasons of low feed availability. Furthermore, *Opuntia* converts water to dry matter or digestible energy far more efficiently than grasses and legumes (De Kock, 1980; 2001; Azocar, 2001). 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. Additional nitrogen (N) was included as an NPN source, namely feed grade urea.

Therefore, this study focused on evaluating two feedlot diets for Dorper wether lambs, containing inclusion levels of about ⅓ sun-dried and coarsely ground *Opuntia cladodes* of the total diet and two different nitrogen sources (NPN and a natural protein). The aim was to determine whether the inclusion of sun-dried and coarsely ground *Opuntia cladodes* or different nitrogen sources in the feedlot diets would affect the feed intake or digestibility by Dorper wether lambs.

MATERIALS AND METHODS

Study area

The study was conducted at Bergvlug Experimental Farm, Ministry of Agriculture, Water and Forestry, Directorate of Veterinary Services, Khomas Region, Namibia. The fieldwork 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 Ministry of Agriculture, Water and Forestry, Directorate of Agricultural Research and Training, Namibia. The selected 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 part 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.

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

Feed ingredient (kg air dry)	Treatment diets*		
	T0	TI	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)

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

Apart from evaluating feed and water intake of all 45 Dorper wether lambs in the feedlot, one replicate of five Dorper wether lambs per treatment diet was moved from the feedlot pens to metabolism cages for a week every third week (namely during weeks 1, 5 and 8) to determine their individual daily feed and water intake and apparent digestibility of the three treatment diets. The daily urine and faecal excretions were also monitored. The experiment lasted until Dorper wether lambs reached a target average slaughter weight of 35 kg per treatment diet.

Chemical analysis of feeds, refusals and faeces

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

Chemical composition of the three treatment diets

The chemical composition of the three treatment diets is presented in Table 2.

Table 2. Chemical composition of the three treatment diets (T0, T1 and T2)

Chemical constituents	Treatment diets*		
	T0	T1	T2
Dry matter (g DM/kg feed)	933,4	898,6	911,1
Crude protein (g CP/kg DM)	153,8	149,0	141,3
Acid-detergent fibre (g ADF/kg DM)	249,9	241,5	228,0
Neutral-detergent fibre (g NDF/kg DM)	465,4	410,5	418,9
Lipids (g lipids/kg DM)	23,8	24,9	25,3
Ash (g ash/kg DM)	72,4	112,0	104,6
Organic matter (g OM/kg DM)	889,8	850,8	860,9
Gross energy (MJ/kg DM)	16,8	15,4	15,9

* 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)

The dry matter (DM) content of the three treatment diets used in this study varied slightly. Zeeman (2005) reported that the DM content of diets decreased with increasing inclusion levels of sun-dried and coarsely ground *Opuntia cladodes*, while Einkamerer (2008) and Menezes (2008) concluded that incremental levels of sun-dried and coarsely ground *Opuntia cladodes* up to an inclusion level of 360 g/kg did not have an effect on the DM content of diets.

The differences in crude protein (CP) content of the diets were relatively small. Every effort was made to balance the diets with regard to CP content (Table 1). However, inclusion of sun-dried and coarsely ground *Opuntia cladodes* in the diets inevitably reduces the CP content of the diets because of the relatively low CP content of *Opuntia cladodes* (Ben Salem *et al*., 1996; Nefzaoui & Ben Salem, 2000; Ben Salem *et al*., 2002; Batista *et al*., 2003). The latter authors concluded that the CP content of *Opuntia cladodes* is much lower than the maintenance requirements of ruminants. Therefore, an NPN source (feed grade urea) and a natural plant protein source (sunflower oilcake meal) were used in this study to balance the N content of the two *Opuntia*-based diets namely treatment diets T1 and T2 and maintain a final CP level required to promote growth as comparable as possible to that for treatment diet T0. It should be noted that treatment diet T0 also contained a small quantity of feed grade urea (Table 1).

Acid-detergent fibre (ADF), neutral-detergent fibre (NDF), organic matter (OM) and gross energy (GE) all decreased slightly with inclusion of sun-dried and coarsely ground *Opuntia cladodes* in the diets (Table 2). In agreement with the *Opuntia* inclusion levels by Zeeman (2005), Einkamerer (2008) and Menezes (2008), the observed results are explained by the lower ADF, NDF, OM and GE content of *Opuntia cladodes*.

The ash content (Table 2) increased with inclusion of sun-dried and coarsely ground *Opuntia cladodes* in the diets. This was expected because of the high ash content of *Opuntia cladodes* (Batista *et al*., 2003). Despite the low lipid content of *Opuntia cladodes* (Zeeman, 2005), the lipid content of the *Opuntia*-based diets showed small increases (Table 2).

Feed intake of Dorper wether lambs in the feedlot

The feed offered and feed refused at two-day intervals for all nine subgroups of five Dorper wether lambs each were recorded to determine the average daily feed intake (Table 3).

No significant differences ($P > 0,05$) were observed between treatment diets (Table 3). However, numerically the feed intake by the Dorper wether lambs fed treatment diet T2 was the highest and those fed treatment diet T1 was the lowest.

Dry matter and nutrient intake and apparent digestibility of treatment diets during the three cage periods

Apart from ash, ADF and NDF, the daily intake (Table 4, Table 5 and Table 6) by Dorper wether lambs of chemical constituents did not differ significantly ($P > 0,05$) among the treatment diets. The values for ADF and NDF were similar for treatment diets T0 and T2, but significantly higher ($P < 0,05$) than for treatment diet T1. The values for ash were higher ($P < 0,05$) for treatment diet T2 than treatment diet T0, but not significantly different ($P > 0,05$) from treatment diet T1. This same trend was observed throughout the three digestibility trials (Cage Periods 1, 2 and 3).

The apparent digestibility coefficients recorded for DM, CP, ADF, GE and OM (Tables 7, 8 and 9) were similar for all treatment diets. Only NDF and lipids showed significantly higher ($P < 0,05$) apparent digestibility for treatment diets T1 and T2 compared to treatment diet T0.

Table 3. The average (mean ± s.e.) daily feed intake by Dorper wether lambs in the feedlot during the study period

	Treatment diets*			P^1	CV^2 (%)
	T0	T1	T2		
Air dry feed intake (kg/day/head)	$1,147 \pm 0,050^a$	$1,131 \pm 0,071^a$	$1,209 \pm 0,022^a$	0,538	7,3
DM intake (kg/day/head)	$1,071 \pm 0,045^a$	$1,016 \pm 0,064^a$	$1,102 \pm 0,020^a$	0,454	7,2
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

Cage periods

Table 4. The daily intake (mean ± s.e.) of DM and chemical constituents of the treatment diets by Dorper wether lambs during Cage Period 1

Intake of chemical constituents	Treatment diets*			P^1	CV^2 (%)
	T0	T1	T2		
Dry matter (g DM/day)	1049,9 ± 80,7^a	775,1 ± 143,9^a	1120,8 ± 126,7^a	0,142	27,4
Crude protein (g CP/day)	168,9 ± 12,2^a	123,4 ± 22,9^a	160,3 ± 18,4^a	0,217	27,2
Acid-detergent fibre (g ADF/day)	282,2 ± 21,3^a	180,2 ± 29,7^b	271,7 ± 26,7^a	0,033	23,9
Neutral-detergent fibre (g NDF/day)	560,4 ± 36,2^a	390,3 ± 61,9^a	559,6 ± 54,7^a	0,062	23,1
Lipids (g lipid/day)	24,2 ± 1,6^a	22,3 ± 3,7^a	32,5 ± 4,1^a	0,109	27,9
Gross energy (MJ GE/day)	18,9 ± 1,5^a	12,7 ± 2,3^a	18,4 ± 2,1^a	0,086	26,6
Ash (g ash/day)	83,0 ± 5,9^b	93,0 ± 16,7^b	140,1 ± 13,8^a	0,020	27,5
Organic matter (g OM/day)	966,8 ± 74,8^a	682,0 ± 127,2^a	980,7 ± 112,9^a	0,127	27,4

* 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

Table 5. The daily intake (mean ± s.e.) of DM and chemical constituents of the treatment diets by Dorper wether lambs during Cage Period 2

Intake of chemical constituents	Treatment diets*			P^1	CV^2 (%)
	T0	T1	T2		
Dry matter (g DM/day)	1294,4 ± 98,6^a	1140,6 ± 164,8^a	1567,4 ± 33,4^a	0,056	18,9
Crude protein (g CP/day)	220,6 ± 16,2^a	187,3 ± 27,0^a	216,9 ± 4,9^a	0,402	19,8
Acid-detergent fibre (g ADF/day)	302,0 ± 25,6^a	412,6 ± 49,9^a	377,3 ± 5,8^a	0,087	20,0
Neutral-detergent fibre (g NDF/day)	584,4 ± 42,6^a	526,0 ± 72,3^a	668,8 ± 10,1^a	0,160	18,5
Lipids (g lipid/day)	36,1 ± 2,7^{ab}	28,5 ± 4,3^b	41,9 ± 1,0^a	0,026	18,9
Gross energy (MJ GE/day)	21,9 ± 1,8^{ab}	18,3 ± 2,6^b	25,3 ± 0,5^a	0,016	19,0
Ash (g ash/day)	99,7 ± 7,3^b	122,8 ± 18,4^b	165,7 ± 4,3^a	0,006	20,2
Organic matter (g OM/day)	1194,8 ± 91,3^a	1017,8 ± 146,4^a	1401,6 ± 29,1^a	0,059	18,8

* 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

Table 6. The daily intake (mean ± s.e.) of DM and chemical constituents of the treatment diets by Dorper wether lambs during Cage Period 3

Intake of chemical constituents	Treatment diets*			P^1	CV^2 (%)
	T0	T1	T2		
Dry matter (g DM/day)	1356,3 ± 74,5^a	1199,8 ± 159,2^a	1533,9 ± 69,6^a	0,138	17,9
Crude protein (g CP/day)	215,2 ± 11,9^a	186,3 ± 23,9^a	247,1 ± 11,6^a	0,073	17,4
Acid-detergent fibre (g ADF/day)	309,9 ± 18,7^a	240,2 ± 29,8^b	344,8 ± 13,8^a	0,016	16,4
Neutral-detergent fibre (g NDF/day)	630,4 ± 33,5^a	443,6 ± 58,7^b	598,4 ± 26,0^a	0,018	16,8
Lipids (g lipid/day)	34,0 ± 2,0^a	32,2 ± 4,6^a	33,7 ± 1,9^a	0,908	20,7
Gross energy (MJ GE/day)	23,3 ± 2,8^a	19,6 ± 2,6^a	26,2 ± 1,2^a	0,068	17,4
Ash (g ash/day)	99,5 ± 6,0^b	129,5 ± 17,0^{ab}	144,7 ± 7,2^a	0,041	20,1
Organic matter (g OM/day)	1256,8 ± 68,6^a	1070,3 ± 142,3^a	1389,3 ± 62,6^a	0,110	17,7

* 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

Table 7. Apparent digestibility coefficients (mean ± s.e.) of DM and chemical constituents of the treatment diets by Dorper wether lambs during Cage Period 1

Chemical constituents	Treatment diets *			P[1]	CV[2] (%)
	T0	T1	T2		
Dry matter (DM)	0,697 ± 0,022[a]	0,718 ± 0,015[a]	0,713 ± 0,011[a]	0,659	5,3
Crude protein (CP)	0,740 ± 0,017[a]	0,772 ± 0,010[a]	0,753 ± 0,009[a]	0,221	3,7
Acid-detergent fibre (ADF)	0,544 ± 0,045[a]	0,642 ± 0,009[a]	0,625 ± 0,012[a]	0,056	10,1
Neutral-detergent fibre (NDF)	0,698 ± 0,024[b]	0,774 ± 0,005[a]	0,757 ± 0,012[a]	0,013	4,8
Lipids	0,629 ± 0,026[b]	0,767 ± 0,046[a]	0,849 ± 0,012[a]	0,001	9,3
Gross energy (GE)	0,696 ± 0,021[a]	0,738 ± 0,012[a]	0,722 ± 0,009[a]	0,169	4,6
Ash	0,418 ± 0,035[a]	0,459 ± 0,043[a]	0,517 ± 0,010[a]	0,136	15,6
Organic matter (OM)	0,721 ± 0,021[a]	0,754 ± 0,013[a]	0,741 ± 0,011[a]	0,359	4,7

* 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

Table 8. Apparent digestibility coefficients (mean ± s.e.) of DM and chemical constituents of the treatment diets by Dorper wether lambs during Cage Period 2

Chemical constituents	Treatment diets *			P[1]	CV[2] (%)
	T0	T1	T2		
Dry matter (DM)	0,731 ± 0,024[a]	0,708 ± 0,073[a]	0,780 ± 0,013[a]	0,527	13,6
Crude protein (CP)	0,787 ± 0,019[a]	0,788 ± 0,052[a]	0,812 ± 0,010[a]	0,832	9,2
Acid-detergent fibre (ADF)	0,572 ± 0,040[b]	0,756 ± 0,062[a]	0,696 ± 0,017[ab]	0,032	14,4
Neutral-detergent fibre (NDF)	0,700 ± 0,027[a]	0,732 ± 0,072[a]	0,759 ± 0,015[a]	0,666	13,9
Lipids	0,715 ± 0,026[b]	0,777 ± 0,055[ab]	0,858 ± 0,007[a]	0,045	10,1
Gross energy (GE)	0,718 ± 0,023[a]	0,728 ± 0,074[a]	0,797 ± 0,011[a]	0,425	13,5
Ash	0,371 ± 0,052[a]	0,356 ± 0,146[a]	0,539 ± 0,033[a]	0,324	48,5
Organic matter (OM	0,761 ± 0,021[a]	0,750 ± 0,065[a]	0,809 ± 0,011[a]	0,561	11,6

* 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

Table 9. Apparent digestibility coefficients (mean ± s.e.) of DM and chemical constituents of the treatment diets by Dorper wether lambs during Cage Period 3

Chemical constituents	Treatment diets *			P[1]	CV[2] (%)
	T0	T1	T2		
Dry matter (DM)	0,684 ± 0,017[a]	0,704 ± 0,058[a]	0,749 ± 0,017[a]	0,451	11,4
Crude protein (CP)	0,730 ± 0,013[a]	0,782 ± 0,039[a]	0,819 ± 0,010[a]	0,074	7,1
Acid-detergent fibre (ADF)	0,486 ± 0,027[a]	0,511 ± 0,099[a]	0,624 ± 0,028[a]	0,276	25,3
Neutral-detergent fibre (NDF)	0,620 ± 0,018[a]	0,612 ± 0,079[a]	0,688 ± 0,022[a]	0,493	17,0
Lipids	0,621 ± 0,026[a]	0,745 ± 0,056[a]	0,754 ± 0,026[a]	0,057	12,3
Gross energy (GE)	0,681 ± 0,018[a]	0,720 ± 0,056[a]	0,764 ± 0,018[a]	0,299	11,1
Ash	0,300 ± 0,046[a]	0,417 ± 0,109[a]	0,438 ± 0,046[a]	0,385	42,7
Organic matter (OM)	0,714 ± 0,015[a]	0,739 ± 0,052[a]	0,781 ± 0,014[a]	0,360	9,7

* 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

These results could be explained by a number of factors. Firstly, the high levels of easily digestible carbohydrates present in *Opuntia cladodes* are positively correlated to increases in apparent DM digestibility of *Opuntia*-based diets (Ben Salem *et al*., 1996; 2004; Misra *et al*., 2006). Secondly, the low fibre content of *Opuntia cladodes* is positively linked to a higher digestibility of a feed, therefore it was to be expected that inclusion of *Opuntia cladodes* would result in a higher apparent digestibility (Nefzaoui & Ben Salem, 2000). Similar results were reported by Menezes (2008). Thirdly, the additional relatively high fibre content of the sunflower oilcake meal may have played a small but unknown role.

Considering the results of all three cage periods, it can be concluded that the daily intake and apparent digestibility of DM and most of the other chemical constituents of the treatment diets by Dorper wether lambs increased or showed very small decreases as the trial progressed from Cage Period 1 to Cage Period 3, regardless of the treatment diets. Einkamerer (2008) also observed a similar trend, which may suggest that with time the Dorper wether lambs became better adapted to the treatment diets in the trial.

The lack of significant differences in most of the chemical constituents of treatment diets in terms of daily intake and apparent digestibility suggest that inclusion of sun-dried and coarsely ground *Opuntia cladodes* in the diets, as well as the different types of nitrogen, did not have a marked influence on those variables.

Water intake in the feedlot and during the digestibility trials

Neither the inclusion of sun-dried and coarsely ground *Opuntia cladodes* in the treatment diets nor the quality of nitrogen in the diet had any significant influence ($P > 0,05$) on the daily water intake by the Dorper wether lambs (Figure 1 and Table 10).

Although not significantly different ($P > 0,05$), the daily water intake by Dorper wether lambs fed treatment diet T2 was higher, followed by treatment diet T0 and for treatment diet T1 it was the lowest (Figure 1). Previous studies by Zeeman (2005), Einkamerer (2008) and Menezes (2008) reported a higher daily water intake by Dorper wether lambs when fed *Opuntia*-based diets.

Overall, the daily water intake by the Dorper wether lambs increased as the feeding period progressed irrespective of the treatment diets. This observation is to some extent in agreement with the results by Einkamerer (2008). The higher water intake may in part be ascribed to the increase in live body weight of the Dorper wether lambs over the trial period, but also the progressive long-term effect of adaptation to the treatment diets.

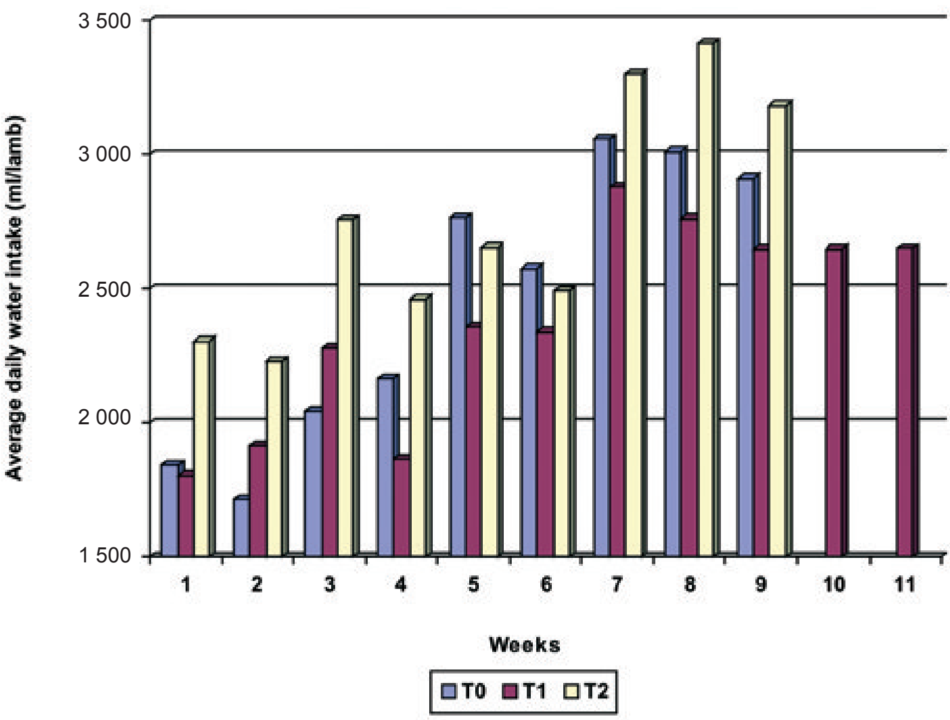

Figure 1. Average daily water intake (ml/lamb) of Dorper wether lambs in the feedlot during the study period.

Table 10. The average (mean ± s.e.) daily water intake during the three cage periods by Dorper wether lambs

	Treatment diets			P^1	CV^2 (%)
	T0	T1	T2		
Cage Period 1 (ml/day)	1831,3 ± 324,9[a]	1840,0 ± 233,5[a]	2002,3 ± 328,0[a]	0,902	35,3
Cage Period 2 (ml/day)	2582,9 ± 165,4[a]	2032,3 ± 273,6[a]	2218,6 ± 196,4[a]	0,229	21,3
Cage Period 3 (ml/day)	2519,7 ± 282,1[a]	2110,9 ± 306,9[a]	2787,4 ± 292,5[a]	0,298	26,6

* 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

Urine and faecal excretion

Inclusion of sun-dried and coarsely ground *Opuntia cladodes* in the treatment diets or the type of nitrogen source used had no significant effect ($P > 0,05$) on the urine excretion (Table 11) by Dorper wether lambs during the three cage periods.

Table 11. The average (mean ± s.e.) daily urine excreted during the three cage periods by Dorper wether lambs

	Treatment diets *			P^1	CV^2 (%)
	T0	T1	T2		
Cage Period 1 (ml/day)	420,3 ± 71,9[a]	571,3 ± 52,6[a]	637,0 ± 138,1[a]	0,291	39,1
Cage Period 2 (ml/day)	573,1 ± 77,3[a]	666,0 ± 106,9[a]	692,3 ± 109,7[a]	0,679	34,4
Cage Period 3 (ml/day)	1102,5 ± 183,7[a]	804,9 ± 135,5[a]	1144,6 ± 187,8[a]	0,341	37,5

* 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

During Cage Periods 1 and 2, no significant differences ($P > 0,05$) were observed in the faecal DM excretion by Dorper wether lambs (Table 12) among irrespective of the treatment diets. However, faecal DM excretion differed significantly ($P < 0,001$) among treatment diets during Cage Period 3. These results are also in line with the lower NDF intake of lambs fed treatment diet T1 during this last Cage Period 3 (Table 6).

Table 12. The average (mean ± s.e.) faecal DM excreted during the three cage periods by Dorper wether lambs

	Treatment diets*			P^1	CV^2 (%)
	T0	T1	T2		
Cage Period 1 (g DM/day)	316,8 ± 80,7[a]	216,4 ± 37,9[a]	321,5 ± 33,0[a]	0,073	25,7
Cage Period 2 (g DM/day)	342,0 ± 20,7[a]	285,7 ± 6,0[a]	343,8 ± 19,3[a]	0,049	11,5
Cage Period 3 (g DM/day)	424,3 ± 6,2[a]	319,1 ± 15,1[c]	381,4 ± 16,7[b]	< 0,001	8,0

* 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,c] Means with different superscripts within a row are significantly different ($P < 0,05$)
[1] Probability
[2] Coefficient of variance

Similar to the daily water intake, urine and faecas excreted by Dorper wether lambs increased as the trial progressed from Cage Period 1 to Cage Period 3, regardless of the treatment diets.

CONCLUSIONS

There is a need to identify alternative feed sources that will support low-cost mutton and lamb production, especially in areas with drought conditions and low rainfall. The utilisation of feed by ruminants is dependent on a variety of inter-related factors that include not only the feed nutritive value, but also intake and digestibility. It can be concluded from the results of this study that comparable feed intake and digestibility can be achieved by Dorper wether lambs fed a conventional feedlot diet and *Opuntia*-based diets with either NPN or natural protein. Therefore, farmers who cannot afford to incorporate lucerne in the feedlot diets can substitute it with sun-dried and coarsely ground *Opuntia cladodes* up to 330 g/kg. However, it is recommended that because of the relative low CP content of *Opuntia cladodes*, additional nitrogen should be supplied as either NPN or natural protein to balance the nitrogen content of *Opuntia*-based diets to maintain the final CP level required to promote the desired growth.

REFERENCES

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

AZOCAR, P., 2001. *Opuntia* as feed for ruminants in Chile. In: Cactus (*Opuntia* spp.) as forage. Eds. Mondragon-Jacobo, C. & Perez-Gonzalez, S. *Plant Production and Protection Paper* 169, 57–62. Food and Agricultural Organization of the United Nations, Rome.

BATISTA, A.M.V., MUSTAFA, A.F., SANTOS, G.R.A., DE CARVALHO, F.F.R., DUBEUX, J.C.B., LIRA, M.A. & BARBOSA, S.B.P., 2003. Chemical Composition and Ruminal Dry Matter and Crude Protein Degradability of Spineless Cactus. *Journal of Agronomy and Crop Science* 189, 123–126.

BEN SALEM, H., NEFZAOUI, A., ABDOULI, H. & ØRSKOV, E.R., 1996. Effect of increasing level of spineless cactus (*Opuntia ficus indica* var. *inermis*) on intake and digestion in sheep given straw based diets. *Journal of Animal Science* 62, 293–299.

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 f. inermis*) and oldman saltbush (*Atriplex nummularia L.*) as alternative supplements for browsing Barbarine lambs given straw-based diets. *Small Ruminant Research* 51, 65–73.

DE KOCK, G.C., 1980. Drought resistant fodder shrubs in South Africa. In: H.N. LeHouerou (ed.) Browse in Africa. The current state of knowledge, 399–408. Papers presented at the International Symposium on Browse in Africa, Addis Ababa, International Livestock Center for Africa.

DE KOCK, G.C., 2001. The use of *Opuntia* as a fodder source in arid areas of southern Africa. In: Cactus (*Opuntia* spp.) as forage. C. Mondragon-Jacobo and S. Perez-Gonzalez (ed.) *Plant Production and Protection Paper* 169, 101–105. FAO, Rome, Italy.

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

KHALAFALLA, M.M., ABDELLATEF, E., MOHAMEED AHMED, M.M. & OSMAN, M.G., 2007. Micropropagation of Cactus (*Opuntia ficus-indica*) as Strategic Tool to Combat Desertification in Arid and Semi Arid Regions. Int. J. Sustain. *Crop Production* 2 (4): 1–8.

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.

MISRA, A.K., MISHRA, A.S., TRIPATHI, M.K., CHATURVEDI, O.H., VAITHIYANATHAN, S., PRASAD, R. & JAKHMOL, 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.

NEFZAOUI, A. & BEN SALEM, H., 2000. *Opuntia*: A strategic fodder and efficient tool to combat desertification in the WANA region. Ed. Inglese, P. CACTUSNET *Newsletter* 2000, 2–24.

SANTOS, G.R.A., BATISTA, A.M.V., MUSTAFA, A.F, DE CARVALHO, F.F.R., DUBEUX, J.C.B., LIRA, M.A & BARBOSA, S.B.P., 2003. Chemical Composition and Ruminal Dry Matter and Crude Protein Degradability of Spineless Cactus. *Journal of Agronomy and Crop Science* 189, 123–126.

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

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.