Chapter 4

Qualitative and Quantitative Intake of *Atriplex nummularia* (Hatfield Select) by Sheep and Goats

4.1 Introduction

In this study the qualitative and quantitative intake of sheep and goats were compared in three periods of grazing. Certain rumen parameters (NH_3-N and VFA) between goats and sheep during a five-day grazing period, were also examined.

The hypotheses were:

- that there is a difference in qualitative and quantitative intake between sheep and goats and goats will select for a higher quality diet;
- that over time the qualitative and quantitative intake will decrease as the availability of edible material decreases;
- that there is a difference in the rumen VFA concentrations between goats and sheep and
- that there is a change in the VFA composition over time, with rumen acetic- and butyric acid concentrations increasing and rumen propionic acid concentration decreasing.

4.2 Materials and methods

4.2.1 Location

These trials were carried out on the Hatfield Experimental Farm of the University of Pretoria, Pretoria, South Africa (28º15'30"E, 25º44'30"S). This experimental farm has an altitude of 1360m. This is a summer rainfall area with November, December and January as the principal rain period. The mean annual rainfall for the Hatfield Experimental Farm, as provided by the Hatfield Experimental Farm's

weather station for the period 2001 to 2004, was 613.28mm. Table 2.1 illustrates the monthly rainfall for this period.

4.2.2 Atriplex population

The same *A. nummularia* population as discussed in Section 2.2.4 and figure 2.1, was used. The fourth unit was used as a transition camp between the trial discussed in Chapter 2 and the trial discussed in this chapter. This unit was also used to ensure that the faeces excreted by the animals during the first day of faecal collection originated from a high quality plant material. Animals utilized this camp for three days only. Unit three was used to take plant material samples selected by the animals. These samples were collected via oesophageal fistulas. These were used to determine the *in vitro* digestibility and intake of the different days on sampling. Rumen fluid was also collected from animals grazing this unit. The rumen fluid was used to determine rumen pH, rumen volatile fatty acid concentrations and rumen ammonia nitrogen concentration as described later.

4.2.3 Animals and housing

All animals were treated with 1ml of Ivomec (Ivermectin)(Bayer) as a precaution against external and internal parasites. The animals were also vaccinated against tetanus and pulpy kidney. Three Dohné Merino x SA Mutton Merino wethers (average mass 60kg) and three castrated Boer goats (average mass 37 kg) were fitted with oesophageal fistulas. Four of each animal type (average mass 72kg and 35kg separately) were fitted with rumen canulae. The goats were fitted with rumen canulae in mid-September 2003 and the sheep for previous studies. All the animals were kept in a pen overnight because of security reasons. The animals were taken to the experimental unit at dawn (05:00) and brought back to the pen at dusk (19:00). They were transported with a vehicle to ensure that the animals did not consume other plant material.

4.2.4 Logistical procedures

The animals were fitted with harnesses, faecal collection bags and oesophageal collection bags a week before the start of the trial. This allowed them enough time to become accustomed to this equipment while grazing on pasture. The animals spent three days in camp four, which allowed them to fill the gastro intestinal tract with high quality plant material and for one day they were allowed to graze camp three, thereby learning the camp and plants. Oesophageal fistula samples were collected from 05:20 to 06:00 on Days 1, 3 and 5. Rumen fluid samples were collected at 06:30, 13:00 and 19:00 on Days 1, 3 and 5. The first rumen fluid samples were collected one hour after the start of browsing. Faeces were collected every day at 04:45 and again at 20:00. Weighing of the animals commenced at 04:30 on the first morning and again on the morning after the last collection of samples.

4.2.5 Preparing experimental animals

4.2.5.1 Oesophageal fistulation technique

A number of systems have been developed to determine the quantity and quality of a grazing or browsing animal's diet. Sampling by the animal is the best way to get a representative sample of the diet selected by the animal (Lesperance *et al.*, 1960). Sampling by the animal was accomplished by the technique as developed by Torrel (1954) with a successful establishment of an oesophageal fistula in a sheep.

For the purposes of this study, four oesophageal fistulated goats and two sheep were prepared. Two of the four sheep used, already had oesophageal fistulas. The technique used for establishment of the fistulated animals is described by Torrel (1954), Cook *et al.* (1958) and Lesperance *et al.* (1960).

For the first week after the operation the wounds were cleaned and disinfected on a daily basis to prevent infection. During this period the animals were fed green chopped Triticale. Intakes were very low and the animals lost weight and

body condition. From the second week the wounds were cleaned every three days and the animals were allowed to graze on a kikuyu pasture. This reduced stress tremendously and intakes increased. They were supplemented with a fully balanced pelleted ration in the pen where they overnight. The animals were allowed 6 weeks for recovery. One of the goats died due to Tetanus (*Clostridium tetani*). The rest of the animals were immediately vaccinated against this bacterium. This forced the use of only three oesophageal fistulated animals of each species.

4.2.5.2 Rumen-fistulation technique

Rumen canulae have a wide range of applications. They can be used for collection of animal selected material (Lesperance *et al.*, 1960), rumen degradability studies (Orskov and McDonald, 1979) and for the determination of rumen NH_3-N and volatile fatty acids (VFA) in rumen fermentation studies.

Four goats were fitted with rumen cannulae, using the technique described by De Waal *et al.* (1983). The sheep used were already fitted with rumen cannulae. During the post-operation period the animals were fed a balanced pelleted diet. They were also allowed to graze a kikuyu pasture during the day from the second week after the operation.

4.2.6 Collecting samples

4.2.6.1 Collecting and preparing oesophageal samples

Samples of material selected by the animals were collected on days one, three and five. These samples were collected by removing the fistula and fitting the animals with collection bags attached around the neck. The fistulae were removed during the morning at 05:20 for 30 minutes to allow enough time for the animal to collect a large enough sample but the time span short enough to prevent the opening in the esophagus to shrink. The bags were then removed and the fistulae refitted to the oesophagus.

Plant material collected in such a manner is contaminated with saliva. The saliva increases the mineral and N concentration (Bath *et al.*, 1956) of the samples and, according to Engels *et al.* (1981), drying the samples with the saliva will lead to large variations in *in vitro* digestibility. The samples were collected and filtered through four layers of cheesecloth (Engels *et al.*, 1981) and the fluid was discarded. This results in the loss of some soluble nutrients but reduces the variation in *in vitro* digestibility and N content. Samples were dried for 48h at 50ºC in a forced draught oven, milled and stored for chemical analysis.

4.2.6.2 Collecting rumen fluid

Rumen fluid was collected three times a day at 06:30, 13:00 and 19:00 on days one, three and five. Rumen contents were collected with the aid of a 60ml syringe connected to a flexible plastic tube. Contents were drawn up from a few locations in the rumen into the tube by the suction caused by the syringe. Approximately 150ml of rumen contents per animal were collected during each sampling period and placed in 250ml plastic bottles in a container filled with ice. The samples were stored like this and immediately after all the samples were collected they were taken to the laboratory where they were filtered through four layers of cheesecloth. The solids were discarded and the rumen fluid preserved as follows:

a) 30ml of the rumen fluid was preserved after each sampling with 5ml of 0.5 M H_2SO_4 and frozen to determine the rumen fluid ammonia nitrogen (NH_3-N) concentration with an auto-analyzer at a later stage;
b) 20ml of the rumen fluid were preserved after each sampling with 1ml of 10% NaOH and frozen to determine the rumen fluid VFA concentration with a gas chromatograph (GC) at a later stage.

Samples from each animal were preserved and analyzed separately, but the three samples of each day were frozen in the same container.

4.2.7 Determination of bodyweight

All the animals were weighed separately on the morning that the trial started at 04:30 and again on the morning after the trial has finished at 04:30. The animals were fasted over night before weighing. The water supply was emptied the night before weighing. This was done to ensure a more reliable empty body mass.

4.2.8 Determination of faecal excretion

For the determination of feed intake it is important to determine the total faecal excretion. It is thus important that all the faeces are collected and that there are no losses. According to Arnold (1962) the total collection of faeces by means of a harness and collection bag is quicker and more accurate than estimating faecal output by means of inert markers such as chromic oxide.

The requirements of such a harness are as follows: it should (a) enable complete collection of all faeces voided, (b) be simple and speedy to operate, (c) cause minimum distress to the animal, so that the animal accustomed to the harness and collection bag behaves normally (Arnold, 1962; Burns *et al.,* 1994).

Faeces were collected twice a day during the five-day grazing period. The faeces were weighed and a representative sample of 10% was taken. The samples were then dried for 48h at 100ºC in a forced draught oven, milled and stored to determine the organic matter content.

4.2.9 Determination of digestibility

Digestibility can be determined by a wide range of methods. The two-stage *in vitro* bioassay is the method of choice for estimating diet quality and has the broadest application (Burns *et al.,* 1994). The process of sampling material with oesophageal fistulated animals, however, results in large variation in the *in vitro* digestibility of a feed. The digestibility was determined using the method as described by Tilley and Terry (1963) and modified by Engels *et al.*, 1981. This method will be discussed in section 4.2.12.

4.2.10 Determination of voluntary intake

Pasture intake was estimated from the ratio of faecal OM voided in the collection bags (Langlands, 1975) and the indigestibility of oesophageal samples by converting the *in vitro* digestibility to *in vivo* digestibility, according to Engels *et al*., 1981.

$$\text{OMI (g/day)} = \frac{100}{(100\% - \text{indigestible OM})} \times \frac{\text{daily OM-excretion}}{1}$$

4.2.11 Chemical analysis

Dry matter and ash

The DM and ash content were determined for faeces and oesophageal fistula samples. This was done with the same method described in Section 2.2.8.

Crude protein

The CP was determined on the oesophageal fistula samples. This was done using the Dumas method (AOAC, 2000), as described in Section 2.2.8.

Neutral detergent fibre

The NDF was determined on the oesophageal fistula samples using the Dosi Fibre system (AOAC, 2000), as described in Section 2.2.8.

In vitro digestibility

The *in vitro* digestibility for the oesophageal fistula samples was determined using the method prescribed by Tilley and Terry (1963). This method consists of an incubation phase in rumen inoculums followed by a digestibility phase in acid pepsin. This method was adapted by Engels and Van der Merwe (1967) by the addition of 20mg nitrogen to the rumen inoculums. With this addition of nitrogen it was found that the origin of the rumen inoculums did not have an effect. The *in*

vivo digestibility was determined with the regression equation suggested by Engels *et al.* (1981) for oesophageal fistula samples:

$Y = 16.4205 + 0.7892X \qquad (r = 0.962; S_{y.x} = \pm 2.0930 ; n = 6)$

Where Y equals the *in vivo* digestibility of organic matter, determined with sheep, and X equals the *in vitro* organic matter digestibility (IVOMD) of oesophageal fistula extrusa of sheep, dried at 50ºC.

Rumen NH_3-N

The rumen fluid samples were defrosted, mixed thoroughly and 10ml centrifuged at 2500 rpm for 15 minutes. The clear fluid was then diluted one hundred times with distilled water and the ammonia nitrogen concentration determined using a Technicon Auto-Analyser (Technicon Auto-Analyser II. Industrial method No 334-74 A, Jan 1976). These values, in parts per million, were corrected for the two dilutions made by multiplying it with 100 and again with 1.1667. This is for correcting for the 5ml of 0.5 M sulphuric acid added to 30ml of rumen fluid in the preservation of the rumen fluid.

Rumen VFA

The samples (rumen fluid/NaOH mixture) were defrosted and 1.1ml of 50% v/v ortho-phosphoric acid was carefully added to 10ml of the sample. This mixture was then centrifuged at 4500 rpm for twenty minutes. Exactly 1ml of internal standard was added to the 9 mm of clear supernatant. The samples were then placed in a refrigerator until required for analysis.

The standard solution was prepared as followed:

Forty ml of cooled (15 ºC) distilled water and 2 ml of ortho-phosphoric acid were added to a 100 ml volumetric flask. The volatile fatty acids were then added to this solution in quantities that are normally present in the rumen. The fatty acids were added in the following quantities: 450 mg acetic acid, 200 mg propionic

acid, 70 mg n-butyric acid, 25 mg iso-butyric acid and 25 mg iso-valeric acid. To this 10 ml of the internal solution was added, the solution was then made up to a volume of 100 ml with distilled water. The internal standard solution consisted of 2000 mg/1000 ml Pivalic acid.

The Varian 3300 gas chromatograph with flame ionisation detector fitted with a 1.8 m glass column (2 mm internal diameter) packed with 60/80 Carbopack C/0.3 % Carbowax 20M/0.1 % H_3PO_4 was used. The column was conditioned overnight at 150 ºC and a flow of 15ml helium per minute.

The analysis was done under the following test conditions:

Carrier gas (Helium) flow:	35 ml/minute
Flame gasses:	Hydrogen and air
Column temperature:	130 ºC
Injection port temperature:	160 ºC
Detector temperature:	180 ºC

One ?l of the standard solution was injected repeatedly until consecutive results were comparable. The samples were then injected in 1 µl volumes and integrated.

4.2.12. Statistical analysis

An analysis of variance with the Proc GLM model (Statistical Analysis System, 1994) was used to determine the significance between different treatments, period and animal effects for the balanced data. Means and standard deviation (s.d.) were determined. Significance of difference (5%) between means was determined by Bonferroni's test (Samuels, 1989).

4.3 Results and discussion

4.3.1 Qualitative intake

In this section the quality of the oesophageal collected *A. nummularia* (Hatfield Select) material is discussed. Special attention is given to the CP, NDF and IVDOM content of this material.

4.3.1.1 Crude protein

The CP concentration of *A. nummularia* (Hatfield Select) edible plant material selected by sheep and goats during five days is illustrated in Table 4.1.

Table 4.1 The %CP of oesophageal samples,selected by goats and sheep browsing *Atriplex nummularia* (Hatfield Select) (DM-basis)

	Goat	Sheep
Day 1	$18.0^{a}{}_{1}$ (± 4.30)	$19.9^{a}{}_{1}$ (± 2.56)
Day 3	$16.0^{a}{}_{1}$ (± 5.98)	$19.6^{a}{}_{1}$ (± 2.28)
Day 5	$3.9^{b}{}_{1}$ (±3.51)	$6.6^{b}{}_{1}$ (± 4.77)

*Different superscript letters within a column indicates significant difference between days (P =0.05)

*Different subscript numbers within a row indicates significant difference between animal spp. (P =0.05)

*Values in brackets represent the standard deviation

In general there was no significant difference in CP selected by goats and sheep during any of the three days. In contrast to our hypothesis, however, that goats would select a higher quality diet, sheep selected a diet higher in CP than goats. This tendency was noted on all three days.

Masson *et al*. (1989) (as cited by EAAP, 1991) did a comparative chemical composition of forage offered and the oeophageal contents between goats and sheep. These authors reported a higher CP concentrations in the oesophageal collected plant material in sheep than in goats. The two species were fed on alfalfa hay with an average CP concentration of 16.2 %. The sheep selected a CP concentration of 16.8 % and the goats of 15.8 %. The same was observed when wheat straw with an average CP concentration of 13.4 % was fed, with

goats selecting a CP concentration of 9.5 % and sheep a CP of 13.3 %. This confirms the tendency from the current study where oesophageal samples of *A. nummularia* (Hatfield Select) selected by sheep had a higher CP concentration than that selected by goats. This is illustrated in Table 4.1. This finding is also contrary to the hypothesis stated in the beginning of this chapter.

Within animal species, there was a significant difference in CP selected over time of *A. nummularia* plant material. For goats there was no significant difference in CP selected during day 1 and day 3, but the CP in material selected on day 5 was significant lower than day 1 and 3. The exact same trend was found for sheep selecting a significantly lower CP on day 5 than on days 1 and 3. The CP value of selected material during day 5 was much lower than the material selected during day 1 and 3. This much lower CP value for selected material during day 5 is because of a shortage in edible material available and not necessarily because of selection. It was the only material available to the animals.

Sparks *et al.* (2003) also noted a decrease in the CP concentration, of oesophageal material collected from *A. nummularia*, towards the end of the grazing period. In that study, CP concentration decreased from 10.2 % CP to 6.3 % CP and 21.1 % CP to 15.9 % CP from the start to the end of the grazing period. In the current study the CP concentration of selected material decreased from 19.9% to 6.6 % CP for sheep and from 18.0 % to 3.9 % CP for goats from the start (day 1) to the end (day 5) of the grazing period. Animals in the current study exhibited a much larger decline in CP % selected than the animals in the study of Sparks *et al.* (2003), but this could be related to the degree of utilization in the respective studies.

When the CP level of grazing drops below 6-8 %, appetite is suppressed and pasture intake by the animal is reduced (Minson, 1982 as quoted by Sparks *et al.*, 2003). From Table 4.1, the CP concentrations on day 1 and 3 were well

above this 6-8 % CP range. By day 5 the CP concentration of diets selected by both goats and sheep were beneath this CP range. This could explain part of the low intakes observed at day 5 and will be discussed later.

4.3.1.2 Neutral detergent fibre

The NDF concentration of *A. nummularia* (Hatfield Select) plant material selected by goats and sheep on three days is presented in Table 4.2.

Table 4.2 The % NDF of oesophagealy collected samples between goats and sheep browsing *Atriplex nummularia* (Hatfield Select) (DM-basis)

	Goat	Sheep
Day 1	$55.4^{a}{}_{1}$ (± 11.31)	$47.4^{a}{}_{1}$ (± 4.33)
Day 3	$60.1^{a}{}_{1}$ (± 16.99)	$48.5^{a}{}_{1}$ (± 3.98)
Day 5	$66.2^{a}{}_{1}$(± 10.70)	$53.1^{a}{}_{1}$ (± 19.06)

*Different superscript letters within a column indicates significant difference between days (P =0.05)

*Different subscript numbers within a row indicates significant difference between animal spp. (P =0.05)

*Values in brackets represents the standard deviation

It is noted from Table 4.2 that there were no significant differences in the NDF concentration of the selected plant material between goats and sheep. Against expectations, sheep selected plant material with a lower NDF value than goats, though not significant. This tendency for sheep to select plant material with lower NDF values was noted on all three days. This means that goats were less selective and most probably consumed more stem material than sheep.

Alcaide *et al.* (1997) reported that goats had a lower daily intake of NDF but a higher intake of NDF/$W^{0.75}$ than sheep on a low quality pasture from a semi-arid land. By converting the data of this author to concentrations, goats selected plant material with 51.6 % NDF (OM-basis) while sheep selected material with 55.84 % NDF (OM-basis). In the current study, the opposite were found, with goats selecting material of a higher NDF concentration.

When the samples collected are compared to each other in terms of NDF value selected by the two species, no significant differences were noted between the three days of collection. Both animal species initially selected plant material of lower NDF during Day 1. As time progressed, NDF value of material collected increased on Days 3 and 5. This increase in NDF value of sampled material over time, is because of a decrease in availability of low NDF edible material and an increase in the stem:leaf ratio. This forces the animals to consume plant material of a lower quality.

Sparks *et al.* (2003) noted a decrease in the NDF concentration of oesophageal material collected from *A. nummularia* plant material from the start to the end of a 50% defoliation grazing trial. This decrease in NDF concentration could not, however, be explained. During a 100% defoliation trial, an increase in the NDF was noted from the start to the end. This increase in NDF concentration was, however, not significant. Increases of between 44.3% to 57.2% and 41.8% to 48.4% were noted from the start to the end of this grazing treatment. The increase in NDF concentration in diets selected by sheep in the current study compares to the increases noted by Sparks *et al.* (2003), but diets selected by goats were higher.

Van Niekerk (1997) also illustrated this increase in NDF concentrations in selected materials from the start to the end of a grazing period. This author reported significant increases of NDF concentrations of oesophageal selected samples of *Digitaria eriantha* (Smuts finger grass) and *Medicago sativa* (alfalfa). NDF concentration increased from 59.0% to 61.1% for *D. eriantha* and from 36.9% to 42.6% for *M. sativa*. The values of *D. eriantha* compare well to the values of Table 4.2. although, these are two totally different species that are being compared.

4.3.1.3 *In vitro* digestible organic matter

In Table 4.3 the chemical analyses for the IVDOM of edible material of *A. nummularia* (Hatfield Select), selected by goats and sheep over five days, is presented.

Table 4.3 The %IVDOM of oesophagealy selected samples between goats and sheep browsing *Atriplex nummularia* (Hatfield Select) (DM-basis)

	Goat	Sheep
Day 1	$59.6^{a}{}_{1}$ (± 8.43)	$66.4^{a}{}_{1}$ (± 10.94)
Day 3	$48.4^{a}{}_{1}$ (± 16.31)	$59.3^{a}{}_{1}$ (± 5.18)
Day 5	$44.9^{a}{}_{1}$ (± 13.14)	$52.4^{a}{}_{1}$ (± 11.71)

*Different superscript letters within a column indicates significant difference between days (P =0.05)

*Different subscript numbers within a row indicates significant difference between animal spp. (P =0.05)

*Values in brackets represent the standard deviation

From Table 4.3 no significant differences in the IVDOM of plant material can be reported between goats and sheep for any of the three days on which oesophageal samples were taken. On all three days, sheep selected, on average, a much higher quality plant material, with a higher IVDOM. This tendency has already been evident in Tables 4.1 and 4.2. In Table 4.2 the sheep selected plant material of a lower NDF concentration than goats. NDF concentration is negatively correlated to digestibility (Reid *et al.*, 1988), thus a selection of higher IVDOM could have been foreseen.

In a study by Louca *et al*. (1982), sheep selected a diet with a higher apparent digestibility than that selected by goats, when fed the same diet. For alfalfa hay consisting of 23.1% CP and 24.1% CF, sheep had a 68.6% apparent digestibility and goats 67.4%. This tendency was also noticed for both barley hay and barley straw. One can assume that the animals were still able to select from these diets fed to them. This difference is the apparent digestibility of DM and can't be compared to Table 4.3, but it gives an illustration that goats selected less

digestible material than sheep. This tendency was also noticed in the current study where sheep selected *A. nummularia* (Hatfield Select) plant material with a non-significant higher IVDOM concentration than that selected by goats.

Within both animal species, there was a tendency to initially select a higher quality diet, with the quality and thus the IVDOM content decreasing towards Day five. For both goats and sheep, the material selected on Day 1 was much higher in IVDOM concentration than Day 3 and 5. There were, however, no significant differences, in IVDOM concentration, between Days 1, 3 and 5. The reason for this is most likely due to animal factors affecting selection of plant material causing large variation between samples. The much lower IVDOM content of plant material at the end of the grazing period, was due to a restriction in the availability of high quality grazeable material. By Day 5 most of the edible leaf material had already been removed. This caused the selection of a diet high in fibre, high NDF (Table 4.2) and low IVDOM (Table 4.3). The higher NDF and lower IVDOM concentration coincides with the finding by Reid *et al.* (1988) that the NDF concentration is negatively correlated with digestibility.

Sparks *et al.* (2003) reported that as with the NDF concentrations, IVDOM of oesophageal *A. nummularia* samples increased from the start to the end of the 50% defoliation grazing period. A decrease in IVDOM concentration was, however, noted in the 100% defoliation grazing period. This decrease in IVDOM concentration was not significant except for one period. During this period the IVDOM concentration decreased from 52.4% at the start of grazing to 43.5% at the end of the period. Starting IVDOM concentrations, in the current study, were higher than those reported by Sparks *et al.* (2003), even though NDF concentrations in the current study were higher than those observed by Sparks *et al.* (2003). The end (Day 5) IVDOM concentrations in the current study compared well with the end IVDOM concentrations of Sparks *et al.* (2003).

Chriyaa *et al*. (1997) reported an IVDMD of 62.2% for *A. nummularia* harvested by hand. This could not be compared to Table 4.3, because it represents the DM digestibility, but it is of interest. Abou El Nasr *et al.* (1996) reported an apparent DM digestibility of 62.6%, while Weston *et al*. (1970) reported IVDMD for *A. nummularia* of 60.8%, which compares to the IVDOM values reported in Table 4.3.

Van Niekerk (1997) reported significantly lower IVDOM concentrations for *D. eriantha* and *M. sativa* at the end of the grazing period than at the start. Van Niekerk (1997) reported a decrease in IVDOM between 69.6% and 61.5% for *D. eriantha* and 66.3% to 63.7% for *M. sativa*. The initial IVDOM concentration of *M. sativa* compared to the IVDOM concentration of *A. nummularia* for sheep in Table 4.3. The IVDOM concentration at the end (day 5) of the grazing period in Table 4.3. was much lower than the IVDOM of either of the two species mentioned above. This could be because of a much lower availability of edible material at the end of the current study. This is a comparison between three totally different species, which should not be compared to each other. This comparison does, however, illustrate the tendency of IVDOM to decrease from the start to the end of a grazing period.

4.3.2 Quantitative intake

In this section the quantity of *A. nummularia* (Hatfield Select) consumed by goats and sheep over a five day grazing period is compared. Special attention is given to OMI, DOMI and DOMI/kg$W^{0.75}$.

Meissner *et al.* (1989) stated that the relationship between NDF and intake is more pronounced than the relationship between IVDOM and intake. This author stated that NDF is related to bulk density of forages which is negatively associated with intake and that NDF includes those components which have the slowest rate of clearance from the rumen.

4.3.2.1 Organic matter intake

The OMI of goats and sheep grazing *A. nummularia* (Hatfield Select) is compared between animal species and day of grazing, in Table 4.4.

Table 4.4 The OMI (g/day) of goats and sheep browsing *Atriplex nummularia* (Hatfield Select) (DM-basis)

	Goat	Sheep
Day 1	525.6^{a}_{1} (±201.59)	482.4^{a}_{1} (± 277.04)
Day 3	435.8^{a}_{1} (± 99.14)	442.6^{a}_{1} (± 186.33)
Day 5	431.7^{a}_{1} (± 113.40)	275.6^{a}_{1} (± 112.88)

*Different superscript letters within a column indicates significant difference between days (P=0.05)

*Different subscript numbers within a row indicates significant difference between animal spp. (P=0.05)

*Values in brackets represent the standard deviation

From Table 4.4 it tends that a higher OMI for day 1 and 5 can be reported for goats than for sheep, while a slightly higher OMI can be reported for sheep during day 3. There were, however, no significant differences in OMI between goats and sheep for any of the three days. Taking into consideration Table 4.2, sheep should have had a higher OMI than goats. This is because NDF concentration is negatively correlated to intake (Abou El Nasr *et al.*, 1996). A higher NDF concentration in the diet, as noted for goats, normally correlates to a lower passage rate of feed particles in the rumen and thus a lower intake (Meissner *et al*., 1989).

There were no significant differences in OMI for either of the two animal species between Days 1, 3 and 5. There was, however, a tendency in both animal species for OMI to decline from Day 1 to Day 3 and Day 5. The OMI decreased by almost 100 g/day for goats between Day 1 and 3. The OMI between Day 3 and 5 was more or less the same. For sheep, OMI decreased with approximately 40 g/day from Day 1 to Day 3. From Day 3 to 5 OMI in sheep decreased 167 g/day. This decrease in OMI, as mentioned above, is because of a decrease in

the amount of available grazing material and an increase in the fibre content of the available edible material. It is interesting to note that OMI in goats decreased after the first day to Day 3 of grazing, while the OMI of sheep decreased at Day 5. It is also interesting to note that the OMI of sheep eventually decreased to a level of 165 g/d lower than goats on Day 5. This could be due to the ability of goats to browse the last leaves between the branches where the sheep could not reach, but this is purely speculative. Another possible reason for the higher intake by goats, on Day 5, could be a higher cellulolytic activity in the rumens of the goats than sheep (Van Soest, 1982). This could cause higher fibre digestion of goats and thus a higher passage rate. Huston (1978) also noticed a higher passage rate of stained feed particles in goats than in sheep, fed on low-quality roughage. This higher passage rate could have caused a higher intake on this high fibre diet on Day 5 by goats.

Sparks *et al.* (2003) reported a decrease in OMI (g/day) of *A. nummularia* between the start and the end of a grazing period. This difference was not significant, but did illustrate the tendency. During some periods of the 50% defoliation treatment, Sparks *et al*. (2003) reported an increase in OMI. Decreases in OMI of between 1101 g/day to 996g/day and 1802 g/day to 1304 g/day were noted between the start and the end of the grazing period. These OMI's reported by Sparks *et al*. (2003) were much higher than the OMI of the current study. Except for the slightly higher NDF (bulky) concentration, animal factors and possible environmental conditions, this difference cannot be explained.

Wilson (1977) on the other hand reported an intake of 432 g/day for sheep which were fed *A. nummularia* leaf material. This low intake compared to the low intakes of Table 4.4. Nutritionally these intakes can't be compared because Wilson (1977) fed leaf material to the animals and the animals were not allowed to graze this material. Weston *et al.* (1970) reported an OMI of 510 g/day for sheep which compares to OMI in Table 4.4 during day 1. This OMI was obtained

by feeding sheep in metabolism cages and should not be compared to the OMI of free grazing animals.

Van Niekerk (1997) reported a significant decrease in OMI (g/day) for sheep grazing *D. eriantha* and *M. sativa* between the start and end of the grazing period. This author reported decreases in OMI of 860 g/day to 674 g/day for *D. eriantha* and 918 g/day to 784 g/day for *M. sativa*. These OMI's were also higher than those reported in the current study. This is not a comparison between species, but it illustrates the decrease in OMI over time within a grazing period.

4.3.2.2 Digestible organic matter intake

Table 4.5 illustrates the DOMI of *A. nummularia* (Hatfield Select) between goats and sheep over a five day period (DM-basis)

Table 4.5 DOMI (g/day) of goats and sheep browsing *Atriplex nummularia* (Hatfield Select)

	Goat	Sheep
Day 1	321.5^{a}_{1} (± 159.32)	339.8^{a}_{1} (± 217.77)
Day 3	220.5^{a}_{1} (± 123.53)	266.4^{a}_{1} (± 120.71)
Day 5	184.5^{a}_{1} (± 10.54)	150.5^{a}_{1} (± 89.44)

*Different superscript letters within a column indicates significant difference between days (P=0.05)

*Different subscript numbers within a row indicates significant difference between animal spp. (P=0.05)

*Values in brackets represent the standard deviation

There were no significant differences in the DOMI of *A. nummularia* (Hatfield Select), between goats and sheep, for any of the three days on which DOMI was determined. During Day 1 and 3, sheep showed a slightly higher DOMI where-as on Day 5 goats showed a slightly higher DOMI than sheep. This difference in DOMI was not of any significance due to large variation in DOMI between animals of the same species. From Table 4.4 it is noted that goats have a larger OMI, but in Table 4.5 a smaller DOMI is observed for goats than for sheep. This is because of the higher IVDOM selected by sheep than by goats.

This higher DOMI by sheep is in contrast to the results of Domingue *et al.* (1991), who reported that goats had higher rumen ammonia concentrations than sheep, when fed on low quality roughages. Alam *et al.* (1983) concluded that this was why goats had a higher DOMI when offered diets with OM digestibilities lower than 60%. Tan *et al.* (1987) showed that this higher DOMI and rumen NH_3-N of goats was not associated to a higher rate of digestion in the rumen, when fed on a low quality forage.

From Table 4.5 there were no significant differences in DOMI of *A. nummularia* (Hatfield Select) between the three days of evaluation within each animal species. Within goats, there was a decrease of approximately 100 g DOMI from Day 1 to Day 3. From Day 3 to 5 DOMI decreased further with approximately 36 g. Within sheep, a 73 g decrease in DOMI was noticed between Day 1 and 3. From Day 3 to 5 an 116 g decrease was noticed. This same tendency was noticed for OMI where goats had a sudden drop in intake shortly after initiation of grazing, while sheep decreased intake at the end of the grazing period.

Van Niekerk (1997) noted a significant difference in the DOMI between the start and the end of the grazing period of both *D. eriantha* and *M. sativa*. This author reported DOMI decreases of 612 g/day to 421 g/day for *D. eriantha* and 620 g/day to 512 g/day for *M. sativa*. This confirms the tendency, noted in Table 4.5, for the DOMI to decrease over grazing period as the availability and quality of grazing material declines.

4.3.2.3 Digestible organic matter intake per metabolic live weight

The DOMI/kg $W^{0.75}$ of goats and sheep grazing on *A. nummularia* (Hatfield Select) is compared in Table 4.6. This was measured on three days over a five-day grazing period.

Table 4.6 The DOMI/kg $W^{0.75}$ (g/day) of goats and sheep browsing *Atriplex nummularia* (Hatfield Select)

	Goat	Sheep
Day 1	21.8^{a}_{1} (± 11.89)	15.5^{a}_{1} (± 9.72)
Day 3	14.2^{a}_{1} (± 5.58)	12.3^{a}_{1} (± 5.31)
Day 5	12.4^{a}_{1} (± 1.06)	7.1^{a}_{1} (± 4.19)

*Different superscript letters within a column indicates significant difference between days (P=0.05)

*Different subscript numbers within a row indicates significant difference between animal spp. (P=0.05)

*Values in brackets represent the standard deviation

Between goats and sheep there were no significant differences in the DOMI/kg $W^{0.75}$. Goats did, however, have a higher DOMI/kg $W^{0.75}$ during all three days of evaluation, even though goats had a lower DOMI in Table 4.5. Because the body weight have such a large influence on DOMI/kg $W^{0.75}$, the higher DOMI/kg $W^{0.75}$ for goats than sheep could be due to a much lower body weight of goats than sheep, but more or less the same DOMI. During Day 1 sheep had a non-significant lower DOMI/kg $W^{0.75}$ than goats. The goats sustained their body weight at 37 kg from the start to the end of the grazing period. The sheep, however, recorded an average loss of 1.5 kg over the same period, going from 60 kg to 58.5 kg from the start to the end of the grazing trial. This decrease in body weight of sheep could have had an influence on DOMI/kg $W^{0.75}$.

In a study by Louca *et al*. (1982), the quantities ingested (g DM/kg $W^{0.75}$) by goats were higher than those ingested by sheep. In a diet of alfalfa hay containing 23.1% CP and 24.1% CF, these authors reported DM intakes of 67.8 g/kg $W^{0.75}$ for goats and 67.0 g/kg $W^{0.75}$ for sheep. This tendency was also noted for barley hay, containing 9.8% CP and 31.4% CF, where intakes of 48.4 g/kg $W^{0.75}$ and 45.1 g/kg $W^{0.75}$ were recorded for goats and sheep respectively. These data by Louca *et al*. (1982) also demonstrates higher intakes per metabolic weight for goats than for sheep. Higher DOMI/kg $W^{0.75}$ were also noted for goats utilizing *A. nummularia* (Hatfield Select) in the current study (Table 4.6). The

higher DOMI/kg $W^{0.75}$ could be because of the larger rumen volume of goats than sheep (EAAP, 1991).

Within each animal species, DOMI/kg $W^{0.75}$ decreased from Day 1 to Day 5. There were no significant differences in DOMI/kg $W^{0.75}$ between the different days, due to variation within the animal species, but the tendency was noticeable. The low DOMI/kg $W^{0.75}$ on Day 5 was because of the low availability of edible plant material at the end of the grazing period.

Sparks *et al.* (2003) reported a non-significant decline in the DOMI/kg $W^{0.75}$/day between the start and the end of a 100% defoliation grazing period. These authors reported declines in DOMI/kg $W^{0.75}$ from 24 g/day to 19 g/day and 37 g/day to 16 g/day for sheep grazing *A. nummularia* to 50 or 100% defoliation respectively. These intakes are slightly higher than the intakes illustrated in Table 4.6. The reason for this difference in intake between these two studies could be because of different grazing pressures and the amount of selection taking place.

Van Niekerk (1997) reported a significant decrease in DOMI/kg $W^{0.75}$ between the start and end of several grazing trials. This author reported DOMI/kg $W^{0.75}$ declines of 46.4 g/day to 29.7 g/day for *D. eriantha* and 44.2 g/day to 32.6 g/day for *M. sativa*. These intakes are much higher than the intakes noted for sheep and goats in Table 4.6. This proves the tendency for DOMI/$kg^{0.75}$ to decrease over the grazing period due to a decrease in availability in high quality grazing material. This tendency was also noticeable in the current study.

4.3.3 Rumen parameters of qualitative intake

In this section some rumen parameters will be compared between goats and sheep grazing *A. nummularia* (Hatfield Select). Rumen parameters at three different stages of the grazing period will also be compared. Attention will be given to rumen NH_3-N and the three most important VFA (acetic-, propionic- and butyric acid).

4.3.3.1 Rumen ammonia nitrogen

"Food proteins are hydrolysed to peptides and amino acids by rumen micro organisms, but some amino acids are degraded further to organic acids, ammonia and carbon dioxide. The ammonia produced, together with some small peptides and free amino acids, is utilised by the rumen organisms to synthesize microbial proteins" (McDonald *et al.*, 1995).

"The ammonia in rumen liquor is the key intermediate in the microbial degradation and synthesis of protein. If the diet is deficient in protein, or if the proteins resist degradation, the concentration of rumen ammonia will be low (5 mg/100ml) and the growth of rumen organisms will be slow. In consequence, the breakdown of carbohydrates will be retarded. On the other hand, if protein degradation proceeds more rapidly than synthesis, ammonia will accumulate in rumen liquor and the optimum concentration will be exceeded. When this happens, ammonia is absorbed into the blood, carried to the liver and converted to urea of which the greater part is excreted via the urine. Estimates on the optimum concentration of ammonia in the rumen liquor vary widely, from 8.5 to over 30 mg/100ml rumen fluid" (McDonald *et al.*, 1995).

The rumen NH_3-N concentrations of goats and sheep, grazing on *A. nummularia* (Hatfield Select), are compared in Table 4.7. Table 4.7 also compares the rumen NH_3-N concentrations at three time intervals of a five day grazing period.

Table 4.7 Rumen ammonia concentration (mg NH_3-N / 100ml rumen fluid) of goats and sheep browsing *A. nummularia* (Hatfield Select)

	Goat	Sheep
Day 1	9.17^{a}_{1} (±1.87)	11.89^{a}_{1} (±4.27)
Day 3	12.02^{a}_{1} (±3.79)	13.41^{a}_{1} (±1.71)
Day 5	8.26^{a}_{1} (±1.38)	10.64^{a}_{1} (±3.52)

*Different superscript letters within a column indicates significant difference between days (P=0.05)

*Different subscript numbers within a row indicates significant difference between animal spp. (P=0.05)

*Values in brackets represent the standard deviation

In a comparison of goats and sheep, the rumen NH_3-N concentrations of goats were lower than those of sheep during the experimental period. This difference was not significant, but it does indicate a tendency for sheep to have a higher rumen NH_3-N concentration on *A. nummularia*. This lower rumen NH_3-N concentration of goats confirms the lower CP concentration in *A. nummularia* (Hatfield Select) selected by goats in Section 4.3.1.1. A CP concentration of diet-selected material is not, however, a direct indication of rumen NH_3-N, because the rumen NH_3-N concentration also depends on the rate of degradation of that CP in the rumen. This is described above. If the extent and rate of degradation and the microbial activity in the rumen were the same for goats and sheep, dietary CP would have been a good indication of rumen NH_3-N.

Dominque *et al*. (1991) noted that the rumen ammonia concentration of goats was higher than that of sheep on low quality roughage. This was not seen in the current study where sheep had a non-significant higher rumen NH_3-N concentration than goats.

From the results in Table 4.7, we could assume a higher rate of N degradation for sheep than goats because of the higher rumen NH_3-N concentrations in sheep. This was, however, not true in this study. Table 2.8 illustrates the rate of N (CP) degradation, for hand harvested edible *A. nummularia* (Hatfield Select)

material, between goats and sheep. Sheep had a non-significant lower rate of N degradation. This could leave us with only one explanation for the higher rumen NH_3-N concentration of sheep. Sheep most likely had a rate of rumen microbe synthesis, which was lower than in goats, causing a less efficient utilization of rumen NH_3-N by sheep. Therefore, sheep had a slightly higher accumulation of rumen NH_3-N in the rumen and thus higher rumen NH_3-N concentrations.

Comparing the rumen NH_3-N concentrations of sheep and goats at three different time intervals, Table 4.7 indicates that there were no significant differences between either of the three days within each animal species. A strange phenomenon can be seen in Table 4.7. The rumen NH_3-N concentrations of Day 3 is higher than Day 1. This goes against expectations, for the rumen NH_3-N concentration to decline as the grazing period progresses. The rumen NH_3-N concentration is, however, the lowest at Day 5, which supports the hypothesis. This low rumen NH_3-N concentration on Day 5 is because of a low availability of available dietary CP as well as the low intakes. A possible explanation for this phenomenon could be that there was a difference in the type of “CP” selected during Days 1 and 3. As can be seen in Table 4.1, the CP concentrations of the plant material selected during Days 1 and 3 was more or less the same, with Day 3 being only slightly lower than Day 1. During Day 1 the animals possibly selected plant material with a higher proportion of undegradable protein leading to lower rumen NH_3-N concentrations. By Day 3, the material left to select from, which had a CP concentration not much lower than Day 1, had a higher degradability of CP and thus the higher rumen NH_3-N concentrations. Another explanation could be that the rumen environment was not favourable for the rumen micro-organisms on Day 3. This could then have caused low utilization of NH_3-N for microbial synthesis and thus accumulation of NH_3-N in the rumen.

Weston *et al*. (1970) reported a 20.1 g N per day intake in Merino wethers fed *A. nummularia*. Of this 20.1 g N, 18.1 g N left the rumen daily. The quantity of N leaving the rumen in the form of ammonia was 3.6 g N daily, thus the quantity of

N leaving the rumen in the form of NAN was 14.5 g daily. The equivalent of 72% of dietary N left the rumen in the form of NAN. The loss of dietary N during the passage of digesta through the rumen, presumably due to the microbial deamination of dietary nitrogenous substances, was reflected by the presence of significant quantities of ammonia in the rumen. The rumen ammonia concentration was 27 mg N/100ml of rumen fluid. An overall digestibility of dietary N of 75.8% was reported. The rumen NH_3-N concentration of this study was significantly higher than that reported in the current study.

Van Niekerk (1997) reported rumen NH_3-N concentrations of 10.9 and 18.7 gN/100 ml of rumen fluid for *D. eriantha* and *M. sativa* respectively. Although an N concentration of only 1.9% (11.88% CP) for *D. eriantha* was reported, the rumen NH_3-N concentration compares well to that of *A. nummularia* (Hatfield Select) with a CP concentration of 18-20% as selected by goats and sheep. This is probably due to a high N loss in the form of NAN as described by Weston *et al.* (1970).

Satter and Roffler (1977) (as cited by Van Niekerk, 1997) stated that the micro organism's activity can be suppressed by rumen NH_3-N concentrations lower than 5 mg/100 ml. None of the rumen NH_3-N concentrations in the current study reached this minimum level and it can be assumed that rumen microbe activity was not detrimentally affected by rumen NH_3-N concentrations. The rumen NH_3-N concentrations were also not high enough to have a negative influence on animal performance. High levels of rumen NH_3-N concentration, need much more energy to be absorbed and transformed to urea, which depletes the body's energy reserve and thus have a negative influence on animal performance (Satter and Roffler, 1977, as cited by Van Niekerk, 1997).

McDonald *et al*. (1995) stated that if the diet is deficient in protein, or if the protein resists degradation, the concentration of rumen ammonia will be low (5 mg/100ml). In the current study, the rumen NH_3-N concentration never dropped

this low with either goats or sheep. This means that dietary protein and rumen protein degradation was sufficient to obtain microbial activity and carbohydrate breakdown in the rumen. These authors also stated that the optimum concentration of ammonia in the rumen liquor vary widely, from 8.5 to over 30 mg/100 ml. In the current study, rumen NH_3-N concentrations were within these boundaries for both goats and sheep, for the whole duration of the grazing period except for goats on Day 5. On Day 5, goats had a rumen NH_3-N concentration of 8.26 mg/100 ml. This is not much under the lower boundary of 8.5 mg/100 ml, but it could mean that dietary protein degradation was slightly slower than rumen microbial protein synthesis for goats on Day 5.

4.3.3.2 Rumen volatile fatty acids

Acetic-, propionic- and butyric acids are the end products of aerobic fermentation of forage in the rumen. These VFA's are the form in which most of the energy from forages is absorbed. There will be a decline in the effectivity in which metabolisable energy is used for production if the proportion of propionic acid declines. Acetic- and butyric acid can only be used for growth if there is enough propionic acid or glucose (Hovell and Greenhalgh, 1978; as cited by Van Niekerk, 1997).

"The relative concentrations of the VFA's are often assumed to represent their relative rates of production, but this may be misleading if the individual VFA's are absorbed at different rates. Their total concentration varies widely according to the animal's diet and the time that has elapsed since the previous meal, but is normally in the range of 7-15 mmol/100 ml. The relative proportion of the different acids also varies. Mature fibrous forages give rise to VFA mixtures containing a high proportion (70%) of acetic acid. Less mature forages tend to give a rather lower proportion of acetic acid and a higher proportion of propionic acid. Grinding and pelleting of forages has little effect on the VFA proportions, when the diet consists of forage alone, but causes a switch from acetic to propionic acid when

the diet also contains concentrates. The concentration of butyric acid is less affected by diet than are acetic and propionic acid" (McDonald *et al.*, 1995).

McDonald *et al*. (1995) stated that the absorption of VFA from the rumen could serve as a chemostatic mechanism of food intake. Intra-ruminal infusions of acetate and propionate have been shown to depress intake of concentrate diets by ruminants. Butyrate seems to have less of an effect on intake than acetate and propionate. It is stated that with diets consisting mainly of roughage, VFA's have a less definite effect on food intake. Thus, we can assume that in the current study, VFA did not have a significant influence on intake.

Table 4.8 illustrates the rumen acetic acid concentrations between goats and sheep grazing *A. nummularia* (Hatfield Select). This Table also compares the three days on which the rumen samples were collected.

Table 4.8 Rumen fluid acetic acid concentration (mmol/100 ml) of goats and sheep browsing *Atriplex nummularia* (Hatfield Select)

	Goat	Sheep
Day 1	$3.85^{a}{}_{1}$ (±1.56)	$3.73^{a}{}_{1}$ (±1.97)
Day 3	$4.51^{a}{}_{1}$ (±0.49)	$4.68^{a}{}_{1}$ (±0.71)
Day 5	$4.19^{a}{}_{1}$ (±0.46)	$2.82^{a}{}_{1}$ (±0.52)

*Different superscript letters within a column indicates significant difference between days (P=0.05)

*Different subscript numbers within a row indicates significant difference between animal spp. (P=0.05)

*Values in brackets represent the standard deviation

In a comparison of goats and sheep, there were no significant differences in rumen acetic acid concentration. During Days 1 and 3 the rumen acetic acid concentration in the two species were similar. On Day 5, however, the rumen acetic acid concentration of sheep was almost two thirds that of goats. This lower rumen acetic acid concentration in sheep on Day 5 is an indication that under the

trial conditions, sheep selected a diet lower in fibre. This can be seen in Table 4.2 where sheep exhibited an insignificantly lower NDF and a lower DOMI than goats. Goats may also have a higher cellulolytic activity in the rumen (Van Soest, 1982), which may contribute to the higher acetic acid concentrations in goats than in sheep. This could also be an indication of the lower DOMI /kg $W^{0.75}$ of sheep on day 5. The lower acetic acid in the rumen fluid could thus be because of the lower total amount of fibre in the diet, which leads to less fibre being digested and thus less acetic acid in the rumen of sheep.

By comparing the different days of sample collection within each species, there was no significant difference in the rumen acetic acid concentration. Within both goats and sheep, the rumen acetic acid concentrations increased from Day 1 to 3. This is because of a combination of an increase in the fibre content of the diet leading to higher acetic acid concentrations and a higher rumen microbe activity as can be seen by the higher NH_3-N concentration (Table 4.7). From Day 3 to 5, there was, however, a decline in rumen acetic acid concentration. The reason for this is unknown, since the fibre content of the diet increased towards Day 5, as can be seen in Table 4.2 This lower rumen acetic acid concentration on Day five is in contrast to all literature that the rumen acetic acid concentration will increase with an increase in fibre in the diet (McDonald *et al.*, 1995). It could be because of the low intakes on Day 5 allowing too low total fibre to be digested and thus less total rumen acetic acid produced. This lower amount of acetic acid is then partly diluted to a greater extent than usual by the rumen fluid. This dilution results then in a lower rumen acetic acid concentration. This could only be true if the amount of rumen fluid is not directly proportional to intake. The decline in the NH_3-N (Table 4.7) can also contribute to the lower rumen acetic acid concentration. This lower NH_3-N indicates a lower rumen microbial activity, which will have a negative effect on the digestion of fibre in the rumen. This negative effect on rumen fibre digestion will cause a decline in the amount of acetic acid produced and thus a lower rumen acetic acid concentration.

No data on the VFA composition of *Atriplex* species could be obtained. A comparison will thus be made with other forage species.

Van Niekerk (1997) reported rumen acetic acid concentrations of 8.5 and 13.8 mmole/100 ml of rumen fluid for *D. eriantha and M. sativa respectively.* These values are much higher than those reported in the current study. The higher rumen acetic acid concentrations for *D. eriantha* and *M. sativa* are not due to a higher fibre concentration but rather due to higher fibre digestion.

From Table 2.9, a high rumen degradability of the cell wall fraction (NDF) for *A. nummularia* (Hatfield Select) can be observed. This high NDF degradation indicates a high fibre digestion, which should cause high rumen acetic acid concentrations. Table 2.10 illustrates high rates of NDF degradation. With such high degradation rates, acetic acid should be produced at a faster rate than at which it can be absorbed by the rumen. This will cause a slight accumulation of acetic acid in the rumen and thus a higher rumen acetic acid concentration. With the extent and rate of NDF degradation in mind, the rumen acetic acid concentration in the current study should have been much higher. The only explanation for the low acetic acid production in the current study could be a less favorable rumen environment on a *A. nummularia* (Hatfield select) pasture than on the milled *M. sativa* hay in the degradability study.

Table 4.9 illustrates a comparison of the rumen propionic acid concentrations in goats and sheep grazing *A. nummularia* (Hatfield Select). This table also illustrates the effect of time of sampling over a five day grazing period.

Table 4.9 Rumen propionic acid concentrations (mmol/100ml) in goats and sheep browsing *Atriplex nummularia* (Hatfield Select)

	Goat	Sheep
Day 1	0.97^{a}_{1} (0.40±)	0.98^{a}_{1} (±0.70)
Day 3	0.95^{a}_{1} (±0.10)	1.04^{a}_{1} (±0.22)
Day 5	0.85^{a}_{1} (±0.11)	0.51^{a}_{1} (±0.11)

*Different superscript letters within a column indicates significant difference between days (P=0.05)

*Different subscript numbers within a row indicates significant difference between animal spp. (P=0.05)

*Values in brackets represent the standard deviation

Between goats and sheep there were no significant differences in the rumen propionic acid concentrations. Comparing goats and sheep on Days 1 and 3, there was not much difference in rumen propionic acid concentration between these two animal species. Sheep did, however, had a slightly higher rumen propionic acid concentration. On Day 5, goats had a nonsignificant higher rumen propionic acid concentration than sheep. The reason for this relatively lower rumen propionic acid concentration in sheep on Day 5 is probably due to the dilution effect of intake discussed previously.

In a comparison of the different days, there were no significant differences in rumen propionic acid concentrations between these days. For both animal species, there was a tendency for the rumen propionic acid concentrations to decline as the grazing period progressed. This is because of an increase in the proportion of fibre that has been consumed as the grazing period progressed, as illustrated in Table 4.2. This increase in proportional fibre consumption leads to an increase in acetic acid production as mentioned and a decrease in the amount of propionic acid produced. Days 1 and 3 for both animal species had more or less the same rumen propionic acid concentration. Towards Day 5, rumen propionic acid concentration showed a relative decrease. From Day 3 to 5 for sheep, the rumen propionic acid concentration more than halved. No explanation can be given for this sudden drop in rumen propionic acid concentration for

sheep on Day 5, except for the increase in NDF concentration and the low intake causing lower total propionic acid produced and thus lower rumen propionic acid concentration as discussed for acetic acid. The decrease in propionic acid concentration is in agreement with the literature, that the propionic acid concentration declines, and acetic acid concentration increases, with an increase in the fibre component of the diet (EAAP, 1991; McDonald *et al*., 1995).

Van Niekerk (1997) reported rumen propionic acid concentrations of 2.3 and 4.7 mmole/100ml of rumen fluid for *D. eriantha* and *M. sativa* respectively. This is much higher than those reported for *A. nummularia* (Hatfield Select) in Table 4.9. These low concentrations of rumen propionic acid concentration can only be explained by the low intakes of the current study causing lower total propionic acid production and thus a lower rumen propionic acid concentration.

Table 4.10 illustrates a comparison of the rumen butyric acid concentrations between goats and sheep grazing *A. nummularia* (Hatfield Select). This Table also illustrates the effect of time on the rumen butyric acid concentration.

Table 4.10 Rumen butyric acid concentrations (mmol/100ml) in goats and sheep browsing *Atriplex nummularia* (Hatfield Select)

	Goat	Sheep
Day 1	$0.47^{a}{}_{1}$ (±0.184)	$0.47^{ab}{}_{1}$ (±0.14)
Day 3	$0.49^{a}{}_{1}$ (±0.07)	$0.60^{a}{}_{1}$ (±0.14)
Day 5	$0.51^{a}{}_{1}$ (±0.07)	$0.33^{b}{}_{1}$ (±0.07)

*Different superscript letters within a column indicates significant difference between days (P=0.05)

*Different subscript numbers within a row indicates significant difference between animal spp. (P=0.05)

*Values in brackets represent the standard deviation

In comparing the two animal species, there were no significant differences in rumen butyric acid concentration. Rumen butyric acid concentration was the same for the two species at day 1, but at day 3, sheep had a higher rumen

butyric acid concentration than goats. By Day 5, goats on the other hand had a higher rumen butyric acid concentration. There was thus no tendency for one of the species to be dominant with respect in rumen butyric acid concentrations.

In a comparison of the different days within each species, it was relevant that goats had a relatively constant rumen butyric acid concentration for Days 1, 3 and 5, while in sheep there was non-significant increase in rumen butyric acid concentration from Day 1 to 3, but a significant decrease from Day 3 to 5. This tendency for rumen butyric acid concentration to increase is because of the increase in fibre in the diet. Rumen butyric acid concentration tends to increase with an increase in diet fibre (EAAP, 1991; McDonald *et al*., 1995). On the other hand, rumen butyric acid concentration showed the same tendency as rumen acetic acid concentration. There was an increase in rumen butyric acid concentration for sheep from Day 1 to 3 with a sudden significant decrease in rumen butyric acid concentration towards Day 5. This sudden drop in rumen butyric acid concentration is against all expectations and can be due to the dilution effect of the lower intake vs. fibre content as discussed previously or because of low microbial activity.

Van Niekerk (1997) reported rumen butyric acid concentrations of 0.8 and 2.1 mmol/100ml of rumen fluid for *D. eriantha* and *M. sativa* respectively. These values are much higher than those reported for *A. nummularia* in Table 4.10.

From the above discussions of rumen acetic-, propionic- and butyric acid concentrations, there was an overall low rumen concentration in all three the VFA's. Sheep had an overall drop in all three VFA on Day 5. All of the results preceding this discussion indicate that these low VFA concentrations, as well as the drop in VFA concentration of sheep on day 5, could only have been due to low intakes. We can conclude from the previous results that low intakes may have a depressing effect on the rumen VFA concentration.

The concentration of VFA resulting from the breakdown of carbohydrates constitutes a good criterion for microbial activity in the rumen. According to El Hag (1976), it was higher in goats than in sheep, regardless of the diet. The difference increased even further as the quality of the forage decreased. Watson and Norton (1982), however, did not report any significant difference between sheep and goats in the concentration of volatile fatty acids in the rumen. VFA concentrations for alfalfa hay, barley hay and barley straw are illustrated in Table 4.11.

Table 4.11 Concentration of VFA's in the reticulo-rumen of goats (G) and sheep (S) (Hadjipanayiotou and Antoniou, 1983)

Diet	Total VFA (moles/l)		Acetic Acid (molar %)		Propionic acid (molar %)		Butyric acid (molar %)	
	G	S	G	S	G	S	G	S
Barley hay	54	75	73	75	18	17	8	8
Alfalfa hay	102	106	80	78	15	16	6	6
Barley straw	28	30	74	76	17	18	8	7

From Table 4.11 it is clear that there are no differences in the proportional VFA composition between sheep and goats. This was partly noted in the current study and is illustrated in Tables 4.8, 4.9 and 4.10. The only difference between animal species was noticed on day five of the grazing period. During this period, sheep had lower VFA (acetic-, propionic- and butyric acid) concentrations than goats.

The ratio of the three most important volatile fatty acids (acetic-, propionic- and butyric acid) are presented in Table 4.12.

Table 4.12 Acetic acid : propionic acid : butyric acid ratio (molar proportions) in goats and sheep browsing *Atriplex nummularia* (Hatfield Select)

	Goat	Sheep
Day 1	0.73 : 0.18 : 0.09 (3.99)	0.72 : 0.19 : 0.09 (3.80)
Day 3	0.76 : 0.16 : 0.08 (4.74)	0.74 : 0.16 : 0.10 (4.49)
Day 5	0.76 : 0.15 : 0.09 (4.92)	0.77 : 0.14 : 0.09 (5.55)

* Values in brackets represents the acetic acid : propionic acid ratio

Table 4.12 illustrates that there were no real differences in the VFA's molar proportions between goats and sheep. This is supported by the findings of Hadjipanayiotou and Antoniou (1983), that there is no difference between goats and sheep in their VFA composition. These authors' finding is illustrated in Table 4.11. There was, however, a tendency for goats to have a higher acetic acid : propionic acid ratio on Days 1 and 3 and for sheep on Day 5. This compares with the individual VFA compositions in Tables 4.8, 4.9 and 4.10. The higher acetic acid : propionic acid ratio in goats agrees with the higher fibre intake of goats in Table 4.2. For future research, a longer grazing period should be investigated to compare goats and sheep in terms of VFA and performance.

In comparing the different days within each animal species, there was a tendency for the proportions of VFA to favor acetic acid towards Day 5. As the proportion of acetic acid increased towards Day 5, the proportion of propionic acid declined, while the molar proportion of butyric acid stayed the same throughout. As the molar proportions of acetic acid increased and propionic acid decreased, the acetic acid:propionic acid ratio also increased towards Day 5. The high acetic acid:propionic acid ratios on Day 3 and 5 indicates a probable shortage of energy towards the end of the grazing period. This is because the increase in the acetic acid:propionic acid ratio causes a decline in the efficiency of utilization of metabolic energy for production (Hovell and Greenhalgh, 1978; as cited by Van Niekerk, 1997). The shortage in energy could also be because of the low DMI.

Van Niekerk (1997) reported molar proportions of acetic-: propionic-: butyric acid for *D. eriantha* of 0.77:0.15:0.07. This compares well with molar proportions obtained in the current study for goats, and especially for sheep, on Day 5. This author also reported a molar proportion of 0.76:0.16:0.08 for *Chloris gayana* (Rhodes grass). These molar proportions compared well with that of goats on Day 5 of the current study. The study of Van Niekerk (1997) was conducted in the winter. This means that the forage was in a dormant phase and of low quality. During summer, when these plants were actively growing again the author reported molar proportions of 0.69:0.20:0.09 and 0.68:0.19:0.09 for *D. erianta* and *C. gayana* respectively. During summer the acetic acid:propionic acid proportions increased. It would be of interest to investigate the effect of season on the VFA composition of *A. nummularia* and to find out if this seasonal effect would be as great as in the above mentioned grasses.

The high proportions of acetic acid in the current study are supported by the high extent and rate of degradation of the cell wall fraction (NDF) of *A.* nummularia (Hatfield Select) as indicated in Table 2.9 and 2.10. A high degree of NDF degradation indicates high digestion of fibre in the rumen and thus a high acetic acid proportion. The high rate of NDF degradation should also increase the acetic acid proportion as the acetic acid is produced faster than it can be absorbed by the rumen.